Fishery Data Series No. 09-68

Steelhead Trout Production Studies at Sitkoh Creek, Alaska, 2005–2006

by

David C. Love

and

Roger D. Harding

December 2009

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Department of Fish and Game	ADF&G
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 09–68

STEELHEAD TROUT PRODUCTION STUDIES AT SITKOH CREEK, ALASKA, 2005–2006

by
David C. Love
Division of Sport Fish, Douglas
and
Roger D. Harding
Division of Sport Fish, Douglas

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

December 2009

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C.777-777K) under Projects F-10-20 and 21, Job R-1-9.

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

David C. Love[a]
Alaska Department of Fish and Game, Division of Sport Fish
802 3rd St., Douglas, AK 99824, P.O. Box 110024, Juneau, AK 99811, USA

and
Roger D. Harding
Alaska Department of Fish and Game, Division of Sport Fish,
802 3rd St., Douglas, AK 99824, P.O. Box 110024, Juneau, AK 99811, USA

[a] *Author to whom all correspondence should be addressed: david.love@alaska.gov.*

This document should be cited as:
Love, D .C., and R. D. Harding. 2009. Steelhead trout production studies at Sitkoh Creek, Alaska, 2005–2006. Alaska Department of Fish and Game, Fishery Data Series No. 09-68, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF FIGURES (CONTINUED)

LIST OF APPENDICES

ABSTRACT

The need for life history information on steelhead trout *Oncorhynchus mykiss* in Southeast Alaska prompted a multi-year study that began in 2003 at Sitkoh Creek. The long-term goal of this project is to estimate the number of steelhead smolt produced per spawner. This information will be combined with data from a habitat-based carrying capacity project to estimate escapement targets. This report summarizes the third and fourth years of the Sitkoh Creek project. An immigrant-emigrant weir was operated from April through June 2005, and from April through June 2006. A total of 543 and 395 adult steelhead trout were counted in 2005 and 2006, respectively. A Chapman estimate for the 2005 escapement was 574 (Bayesian SE = 4.7), and for 2006 it was 416 fish (Bayesian SE = 3.5). All untagged adult steelhead captured in 2005 and 2006 were given passive integrative transponder (PIT) tags and released upstream. Scale analysis estimated that 44% of the adults sampled in 2005 were first-time spawners; in 2006, 46% were first-time spawners. Approximately 63% of the kelts survived spawning during 2005 and were successfully passed downstream through the weir; during 2006, 71% survived. During 2005 and 2006, all untagged kelts were PIT-tagged and released downstream. During 2005, 2,230 steelhead smolt, 2,787 sea-run cutthroat trout, and 38,422 sea-run Dolly Varden emigrated downstream. During 2006, 3,561 steelhead smolt, 2,491 sea-run cutthroat trout, and 29,820 sea-run Dolly Varden emigrated. Additionally, 2,226 and 3,549 steelhead smolt were measured and PIT-tagged before being released downstream in 2005 and 2006, respectively. In 2005, one smolt was recaptured passing downstream through the weir for a second year in a row. Scale aging of 2005 smolts estimated that 16.4% were 3 years old and 54.5% were 4 years old, and in 2006 34.3% were 3 years old and 41.2% were 4 years old.

Keywords: Steelhead trout, *Oncorhynchus mykiss*, Sitkoh Creek, sustainable yield, smolt and adult production, post-spawning mortality, length frequency distribution, weir, PIT tag, scale sampling, Dolly Varden char, cutthroat trout.

INTRODUCTION

Steelhead *Oncorhynchus mykiss* in Alaska are found in coastal streams from Dixon Entrance to the Alaska Peninsula. Southeast Alaska has 309 watersheds known to support annual escapements of steelhead. Most of the known steelhead streams in Southeast Alaska are believed to contain 200 or fewer adults. However, some of the larger systems, like Karta River, may have once supported annual escapements >1,000 adult steelhead, while the Thorne River watershed is still believed to have an annual escapement >1,000. The largest known steelhead producer in Southeast Alaska is the Situk River near Yakutat, which has annual kelt counts that vary from 3,000 to just over 15,000 adults. The smaller populations of steelhead in Southeast Alaska may be especially vulnerable to overexploitation if recreational or subsistence harvests significantly increase. Thus, there is a need to conservatively manage these relatively small populations of steelhead in Southeast Alaska. This project is designed to collect the data necessary to develop and support management ensuring there is adequate escapement (broodstock) to produce the numbers of smolt needed to fully utilize available freshwater habitat. The specific research emphasis of this project is to collect demographic parameters needed for evaluating steelhead smolt production relative to adult escapement. Estimates of smolt per spawner, combined with results from our companion steelhead carrying capacity project (Crupi et al. *In prep*), will provide the information necessary to estimate adult and smolt utilization of spawning, rearing, and overwintering habitats.

Although the long-term objective of this project is to estimate smolt per spawner, several other demographic parameters will also be obtained coincidental to this goal. Researchers may ultimately be able to estimate repeat spawning rates and smolt-to-adult survival for Sitkoh Creek steelhead, as well as document scale patterns of known ocean-age adult steelhead returning to spawn; these estimates may prove useful in guiding management actions. This report summarizes the third and fourth years (2005 and 2006) of a planned 7-year study and presents information on the steelhead immigration and emigration, length distributions, tagging, and preliminary scale-aging methodology. Emigrant counts and length frequency distributions of sea-run cutthroat trout and Dolly Varden char are also summarized.

STUDY AREA

Sitkoh Creek was chosen for this long-term study because it has a moderately large population of steelhead, a history of successful weir studies, relatively intact habitat, is a steelhead index stream, and supports a valued fishery. The Sitkoh Creek system is located on southeastern Chichagof Island in Southeast Alaska (Figure 1), and empties into Chatham Strait via Sitkoh Bay. Sitkoh Creek (ADF&G Anadromous Stream Catalog No. 113-59-10040) is about 6.4 km long, 10 to 30 m wide, 0.1 to 3 m deep, and drains Sitkoh Lake. Sitkoh Lake has a surface area of 189 ha, a maximum depth of 42 m, and is located approximately 59 m above sea level. The U.S. Forest Service (USFS) maintains two popular public-use cabins on Sitkoh Lake that are accessible by floatplane and logging roads. Sitkoh Creek is also accessible by boat from Sitka or Juneau and attracts anglers from all urban centers of northern Southeast Alaska (Jones 1983).

Steelhead trout from Sitkoh Creek were monitored eight times prior to 2005 with weirs operated in 1936, 1937, 1982, 1990, 1993, 1996, 2003 and 2004 (Chipperfield 1938; Jones 1983; Jones et al. 1991; Harding and Jones 1994; Yanusz 1997; Love and Harding 2008); escapement counts ranged from 520 to 1,108 and averaged 764 fish (Table 1). On average, the Sitkoh system (creek and lake) ranked third highest in estimated steelhead catch during 1997–2006 for all freshwater systems in Southeast Alaska. However,

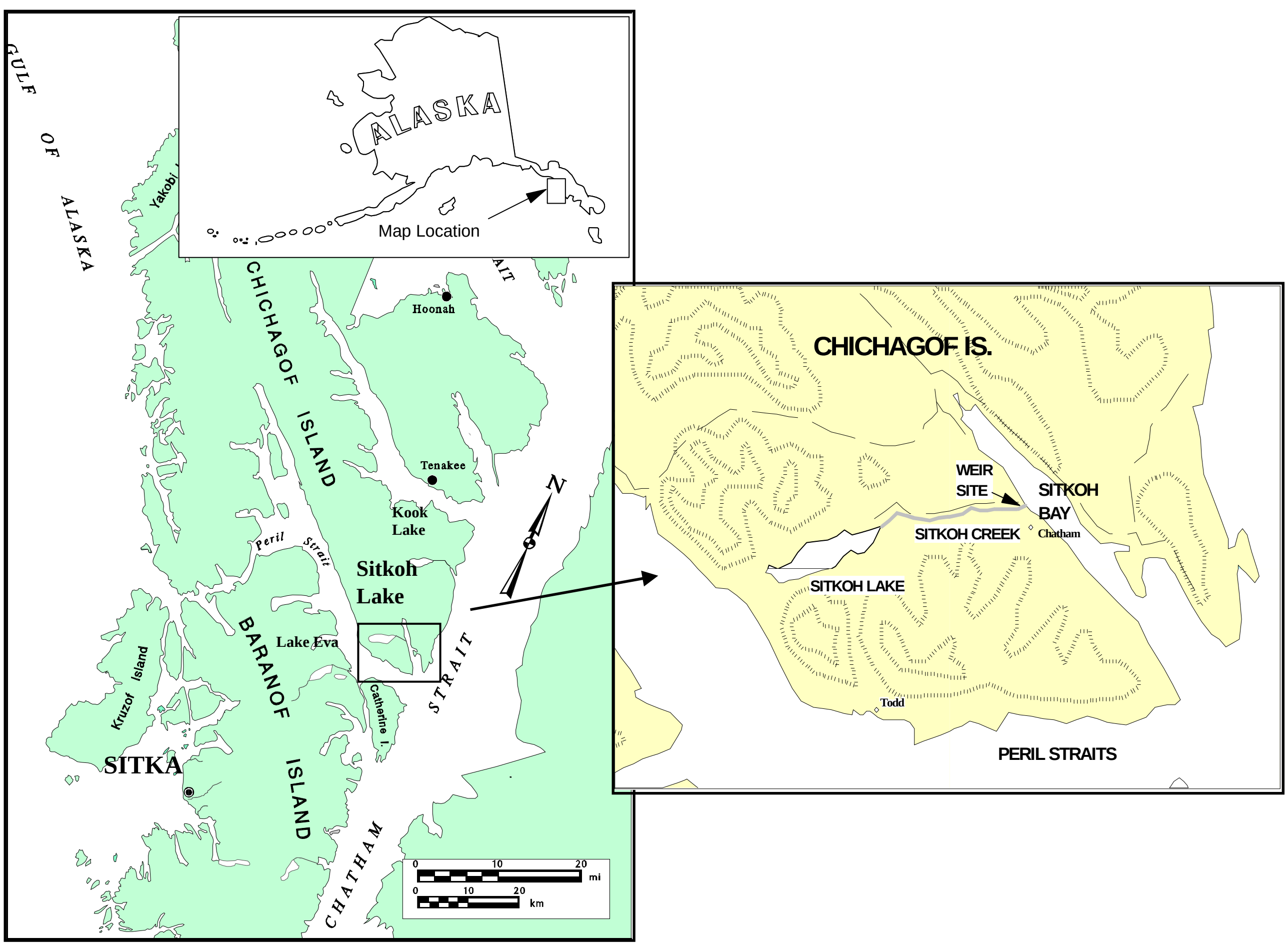


Figure 1.–Location of Sitkoh Lake, Sitkoh Creek, and weir site on Sitkoh Creek.

Table 1.–Historical steelhead escapement census and sex composition of steelhead escapement at Sitkoh Creek for weir counts made during 1936 to 2006. Data for 1936 and 1937 from Chipperfield (1938); 1982 data from Jones (1983); 1990 data from Jones et al. (1991); 1993 data from Harding and Jones (1994); 1996 data from Yanusz (1997); 2003–2004 data from Love and Harding (2008).

Year	Escapement count	Proportion female	Proportion male
1936	760		
1937	1,108		
1982	690	0.5	0.5
1990	661	0.61	0.39
1993	520	0.63	0.37
1996	926	0.62	0.38
2003	679	0.62	0.38
2004	764	0.60	0.40
Average	764		
2005	543	0.67	0.33
2006	395	0.65	0.35

reported effort has been lower during recent years (Howe et al. 2001a-c; Walker et al. 2003; Jennings et al. 2004; 2006a-b, 2007; Jennings et al. 2009a-b). Current angling regulations permit retention of steelhead ≥36 inches (914 mm) TL, thus effectively protecting 96–98% of the fish in Sitkoh Creek during the 2003–2006 period (Love and Harding 2008).

METHODS

An aluminum bipod weir was installed on Sitkoh Creek in 2005 and 2006. The weir contained separate emigrant-immigrant traps (2.5-m square) and was located approximately 400 m upstream from tidewater. This was the same site used during previous studies in 1982, 1990, 1993, 1996, 2003 and 2004. The weir was comprised of 18-mm diameter steel pickets spaced no more than 31 mm apart. The upstream face of the weir was overlaid with 1.2 m by 1.8-m frames covered with vinyl-coated wire mesh (10 x 18-mm openings). The mesh and frames were attached to the weir with cable ties, and the entire interface of the mesh and the streambed was skirted with plastic fencing (18.75-mm square openings) and covered with sandbags. Both the wire mesh and plastic fencing were believed to safely block the passage of fish ≥150 mm FL. Picket and channel holding pens were placed on both the upstream and downstream sides of the weir to hold captured fish entering and exiting the system. Plastic fencing was overlaid on both traps to create a barrier for fish ≥150 mm. The weir was scheduled to be operated from early April until to the last week of June during each sample year. During both years, there were no adjustments made to the structure of the weir or its position in the creek during any period of its operation. Weir integrity was checked several times daily, and fish in each trap were processed whenever necessary to avoid crowding and mitigate stress. Water temperature and water depth were recorded at approximately 12:00 each day during 2005 and 2006.

ADULT STEELHEAD

All immigrating adult steelhead were counted, measured to the nearest 1 mm FL, and a subsample was measured for TL (current sport fish regulations are based on TL, and additional comparison between FL and TL was desired). Newly captured adults were categorized by sex using secondary sexual characteristics, and tagged with 134 kHz passive integrative transponder (PIT) tags. PIT tags were implanted into the left side of the fish just under the skin and posterior to the cleithrum. Entrance wounds caused by PIT tag insertion were treated with iodophore and sealed with a drop of cyanoacrylate glue. Newly-tagged fish were secondarily marked by removing the adipose fin. During 2005 and 2006, all immigrating adult steelhead were checked for adipose clips and previously-implanted PIT tags, measured, and passed upstream through the weir.

A systematic subsample of scales was collected from immigrating adult steelhead each year. Scales were removed from an area approximately 4-6 scale rows below and behind the dorsal fin, but above the lateral line. Untagged fish had 4 to 5 scales removed from the left side, and scales from previously-tagged fish were removed from the right side. Scale samples were placed on labeled gum cards and pressed flat in sequential order for storage. Detached adipose fins were collected from 50 adults and preserved in 70% ethanol for later genetic sequencing by the U.S. Fish and Wildlife Service Genetics Laboratory in Anchorage.

All kelts were counted and checked for the presence of an adipose fin and PIT tag. If a tag was not present, the fish was PIT-tagged, marked with an adipose finclip, measured, and sexed. If a fish had a PIT tag but was not finclipped, the adipose fin was removed and this was noted on the data forms accordingly.

Daily and cumulative numbers of adult fish passing through the weir were recorded in 2005 and 2006. Because all adult steelhead were measured during the period the weir was operable, the length composition of immigrant steelhead passed through the weir was known for both years. The weir was fish tight and was not breached during the sample period in 2005 and 2006. Nonetheless, 23 and 22 unmarked fish were captured during the emigration in 2005 and 2006, respectively. An estimate of total immigration was made using the Chapman modification to the Petersen estimator (Seber 1982):

$$\hat{N} = \frac{(C+1)(M+1)}{R+1} - 1 \qquad (1)$$

where:

$\hat{N}$ = estimated abundance of steelhead;

M = the number uniquely marked steelhead passed upstream through the weir;

R = the number marked steelhead from M passed downstream through the weir; and,

C = the total number of steelhead passed downstream through the weir.

Variance and 95% credibility interval for the estimator (equation 1) were estimated using empirical Bayesian methods (Carlin and Louis 2000). Using Markov Chain Monte-Carlo techniques, a posterior distribution for $\hat{N}$ was generated by collecting 200,000 simulated values of $\hat{N}$ that were calculated using equation (1) from simulated values of equation parameters. Simulated values were modeled from observed data using a multinomial distribution for the proportions of the following classifications of steelhead in the spawning population:

M-R: the number of uniquely marked steelhead passed upstream through the weir that were not later observed passing downstream through the weir;

C-R: the number of steelhead passed downstream through the weir that were not observed during the passage of steelhead upstream through the weir;

R: the number uniquely marked steelhead passed upstream through the weir that were later observed passing downstream through the weir;

$\hat{N}$*-M-C+R*: the number of steelhead that were not observed while passing fish either upstream or downstream through the weir.

At the end of the iterations, the following statistics were calculated:

$$\overline{N} = \frac{\sum_{b=1}^{200,000} \hat{N}_{(b)}}{200,000} \qquad (2)$$

and

$$V\hat{a}r(\hat{N}') = \frac{\sum_{b=1}^{200,000} (\hat{N}_{(b)} - \overline{N})^2}{200,000 - 1} \qquad (3)$$

where $\hat{N}_{(b)}$ is the *b*th simulated observation.

In addition to abundance estimation, a regression model (R^2 = 0.98, P = 3.72e-41) was developed using length data from 11 different streams in Southeast Alaska and across years between 1994 and 2006 (Harding et al. 2009) to estimate TL from FL for all steelhead in Sitkoh Creek during 2005 and 2006:

$$\text{TL (mm)} = 24.459689 + 1.0033394 * \text{FL (mm)} \qquad (4)$$

The model was used to estimate the number of male and female adult steelhead of legal harvestable size (i.e., ≥36 inches TL).

STEELHEAD SMOLT

All emigrant steelhead smolt ≥150 mm were counted, examined for PIT tags, measured to the nearest 1 mm FL, PIT-tagged if untagged, and adipose finclipped. Steelhead smolt were anesthetized using a buffered MS-222 solution prior to sampling. In 2005 and 2006, 134 kHz PIT tags were implanted in all steelhead smolt. PIT tags were implanted into the left side of the fish just under the skin and just posterior to the cleithrum. Entrance wounds caused by PIT tag insertion were treated with iodophore and sealed with a drop of cyanoacrylate glue. Newly-tagged fish were secondarily marked by removing the adipose fin. Scars created by removal of the adipose fin were also treated with iodophore. All emigrating juvenile steelhead were checked for adipose clips and previously implanted PIT tags prior to sampling.

Scales were collected from a systematic subsample of emigrant steelhead smolt. Scales were removed from an area approximately 4-6 scale rows below and behind the dorsal fin, but above the lateral line. Untagged fish were sampled on the left side, and previously-tagged fish were sampled on the right. About 15-20 scales were removed from each sampled fish and were evenly spaced on clear glass slides. A second glass slide was secured over the first to protect the samples. Slides were stored inside a coin envelope inscribed with the sample number. Coin envelopes were stacked in sequential order and stored for aging.

Once steelhead smolt had been scale sampled, they were placed into large flow-through wire mesh fish boxes (10 mm-square openings) within the downstream trap for recovery, and the lid was kept closed. After fish had visibly recovered, they were released into the stream if light levels were low, or held inside the wire mesh fish boxes until low light conditions so that predation was reduced. All smolt mortalities were counted, measured to the nearest 1 mm FL, and sampled for scales and otoliths. If PIT-tagged, mortalities were necropsied to assess tag placement and improve tagging techniques.

We assumed that all steelhead smolt >150 mm FL were retained by the vinyl-coated wire mesh used to cover the face of the weir. Steelhead smolt counts for both 2005 and 2006 were considered to be census counts, resulting in no need to consider a Chapman estimator for smolt abundance. Emigrant steelhead juveniles <150 mm FL could pass through the weir without being captured. These smaller fish represented an unknown percentage of the total emigration and were not considered as smolt for this project. All juvenile steelhead <150 mm FL were counted, measured to the nearest 1 mm FL, subsampled for scales, and released. Otoliths were collected from mortalities.

STEELHEAD SCALE AGING AND ELECTRONIC IMAGING

Scale samples were imaged using an Indus International Microfiche reader[1] and electronic imaging software. Methodology used to estimate ages from electronic scale images was similar to that used by Ericksen (1999) for cutthroat trout, and by Jones (*Undated/Unpublished*) for steelhead trout. As described in Erickson (1999), scale ages were determined primarily from the area of the scale lying 45^{o} off either side of an imaginary reference line drawn along the longest axis of the scale, from the focus to the anterior edge. Patterns were often more evident in this area of the scale. Ideal scales were clean, mucus-free, and did not have a regenerated focus. Scale ages were considered to be estimated, not determined, because known-aged samples were not available (Ericksen 1999). To minimize bias between readers, to date there is one primary scale aging technician that estimates ages of all steelhead. This scale-aging technician made three independent readings of each sampled scale to estimate age. If none of the three reads agreed, the sample was considered unreadable and was omitted from the age composition estimation. The modal age of the three scale-age readings was taken as the most consistent age and was reported. Assuming that a matching scale age, if not accurate, was the most consistent estimate, it was concluded that this final age was the best estimate. Between readings, the scale images were randomized by the project biologist and scale aging results from the previous reading(s) were not known during subsequent readings. All reads were archived for assessing aging errors. Criteria for aging juvenile and smolt scales included: rejection of latinucleate scales, overall scale size, average number of annual circuli relative to year of growth, identification of annuli, and identification of "plus growth." These criteria

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

were used to develop aging "rules," which were incorporated into the scale-aging methodology and then periodically re-evaluated if warranted.

Aging of scales samples collected from immigrant adults and emigrant smolts in 2005 and 2006 was completed. Ocean ages of repeat spawning and skip spawning adults, as well as "known ocean age" at initial spawn of previously-tagged smolt, will be obtained. The "scale read" ocean age will then be compared to "known ocean age" based on PIT tag capture history. Tallies of the differences between true and estimated ocean ages will be compiled over time to determine bias in readings. Functionally significant differences between the two measures of ocean age (i.e., more that 0.5 years different on average) will be investigated to determine if the ocean-age reading criteria based on scales can be modified to improve reading accuracy. Scale-based age estimates for both adult and smolt steelhead sampled during all years of the study, electronic imaging and archive methodology, and aging criteria will be summarized in a separate report.

CUTTHROAT TROUT AND DOLLY VARDEN CHAR

All downstream-migrating Dolly Varden char and cutthroat trout were counted and checked for the presence of tags or marks applied during previous studies in Sitkoh Creek. Length to the nearest 1 mm FL was collected from a subsample of Dolly Varden char and cutthroat trout captured on a daily basis. Scales were not collected from either species.

Size composition of migrant Dolly Varden char and cutthroat trout was estimated using the following equation:

$$\hat{p}_a = \frac{n_{\mathrm{a}}}{n} \tag{5}$$

$$\hat{\mathrm{var}}[\hat{p}_a] = \left(1 - \frac{n}{N}\right)\frac{\hat{p}_a(1 - \hat{p}_a)}{n - 1} \tag{6}$$

where $\hat{p}_a$ = estimated proportion of group a (size group), n_a = number of sampled fish in group a, N = total number of fish in the emigrating population, and n = number of fish successfully measured for length.

RESULTS

2005

Adult Steelhead-Immigration

The Sitkoh Creek weir was continuously operated from 7 April through 25 June, 2005. A total of 538 adult steelhead were passed upstream through the Sitkoh Creek weir during 2005. Every untagged adult immigrant received a new PIT tag and an adipose finclip. Five additional untagged kelts passed downstream were also captured. Adding these to the immigrant count gives a minimum total known census of 543 fish. The Chapman estimate for Sitkoh Creek steelhead abundance was 574 (Bayesian SE = 4.7, 95% credibility interval = 564.8 to 583.5).

Scale samples were collected from 245 immigrant steelhead, or 45% of the total adult escapement. Electronic scale images were created and archived. Analysis of the scale images estimated that 44% of the steelhead passing upstream through the weir were first-time spawners. Eight age classes were identified among first-time spawners; ages 3.2 (10.2%) and x.2 (i.e., unknown freshwater age, 12.2%) dominated. Age class 4.2 equaled 3.3% of the total (n = 8). Two-ocean first-time spawners (n = 63) represented 25.8% of the escapement. Three-ocean, first-time spawners aged at 3, 4 and 5 freshwater (n = 45) were second-most prevalent as a group at 18.4% (Table 2).

The first adult was captured in the upstream trap on 8 April, and the last on 23 June. The peak daily count (44) occurred on 2 May, and the midpoint of the run, on 30 April. Upstream migration seemed to follow periods of increased water levels (Figure 2). Females made up the majority of the immigrants at 67% (364 fish), and males represented 33% (179 fish, Table 1). Although female immigrants were more abundant overall, roughly equal numbers of males and females moved upstream through the weir prior to 30 April. After 30 April, proportionately more females than males immigrated into Sitkoh Creek (Figure 3). The spawning immigration was largely complete by 31 May, when the cumulative proportion of females to males was about 2:1.

Table 2.–Age composition of Sitkoh Creek steelhead adults sampled in 2005 and 2006. Estimated ages based on three independent readings of a scale sample by the same scale-aging technician.

	2005		2006	
Class	*n*	%	*n*	%
2.3	0	0.0	1	0.5
3.2	25	10.2	11	5.5
3.3	6	2.4	20	10.0
3.4	1	0.4	0	0.0
4.2	8	3.3	21	10.5
4.3	16	6.5	22	11.0
5.3	3	1.2	0	0.0
2.2s1s1	1	0.4	0	0.0
3.2s1	25	10.2	10	5.0
3.2s1s1	5	2.0	4	2.0
3.2s1s1s1	0	0.0	1	0.5
3.3s1	6	2.4	0	0.0
4.2s1	27	11.0	23	11.5
4.2s1s1	4	1.6	7	3.5
4.2s1s1s1	0	0.0	1	0.5
4.3s1	3	1.2	1	0.5
5.2s1	4	1.6	0	0.0
5.2s1s1	2	0.8	0	0.0
x.2	30	12.2	4	2.0
x.2s1	25	10.2	14	7.0
x.2s1s1	4	1.6	4	2.0
x.2s1s1s1	0	0.0	1	0.5
x.3	20	8.2	12	6.0
x.3s1	9	3.7	5	2.5
x.4	0	0.0	1	0.5
No match	9	3.7	34	17.0
Unreadable	12	4.8	3	1.5
Total sampled	245		200	
% not readable	21	8.5	37	18.5

The length measurements of all immigrant steelhead passed through the weir averaged 753 mm FL (SD = 70.2 mm) and ranged from 550 to 935 FL mm (*N* = 541). Proportionately more fish >750 mm FL were females and fish <750 mm were predominately males (Figure 4). The length for all males averaged 741 mm FL (SD = 92.4 mm; *N* = 180); for females, length averaged 759 mm FL and SD = 54.9 mm (*N* = 356). In addition to fork length, total length was measured on 539 fish. These data were included in the Southeast regionwide regression model (Harding et al. 2009). In 2005, 13 fish (2.4 % of the total immigrant steelhead run) met the minimum length requirements for sport fish retention (Table 3).

Of the total adult immigration, 23% (123) were recaptured fish that were initially PIT tagged as smolts or adults during the prior 2 years (Table 4). Fish identified as first-time spawners were all initially tagged as smolts during 2003 (i.e., 2-ocean fish), and composed 43% of the total recaptured fish; more first-time spawners were males. Repeat spawning adults tagged in 2003 and 2004 represented 2.3%, and 45.5% of the total recaptured fish, respectively. The ratio of female to male repeat spawners was 2.4:1, as compared to a sex ratio of 2.0:1 for the entire escapement, which included first time, repeat and unknown origin adult spawners. Approximately 4% of the tags (five tags) were either faulty and could not be read, or did not match archived PIT tag numbers for Sitkoh Creek. The natal source stream and smolt emigrant year of the remaining 415 untagged adult fish was not known.

Adult Steelhead-Emigration

In 2005, 363 kelts emigrated from Sitkoh Creek. Of these, 358 had been previously marked during their upstream migration, and five were untagged, i.e., no adipose finclip or PIT tag. The first fish was captured emigrating from Sitkoh Creek on 4 April, the last was captured on 23 June, and the midpoint of the emigration was on 31 May. The peak daily downstream count (48) occurred on 13 May (Figure 2). The fork length of all measured emigrant steelhead averaged 752 mm FL (SD = 66.7 mm) and ranged from 550 to 912 mm FL (*n* = 339). Emigrant females varied less in length and were generally slightly longer than males. The length of females averaged 759 mm FL and had a SD of 54.1 mm, versus the length of males, which averaged 729 mm FL and had a SD of 92.2 mm. From 3 May to 23 June, more females (62.7%) emigrated from the system following spawning than did males, similar to the sex ratio of the spawners entering the system (66.5%). One moribund adipose-clipped fish captured in the downstream trap appeared to have lost a tag due to an otter bite and was not retagged. All five untagged emigrant fish were PIT-tagged, sexed, and measured. Post-spawning survival was approximately 63.2% (363 emigrants/574 immigrants) in 2005.

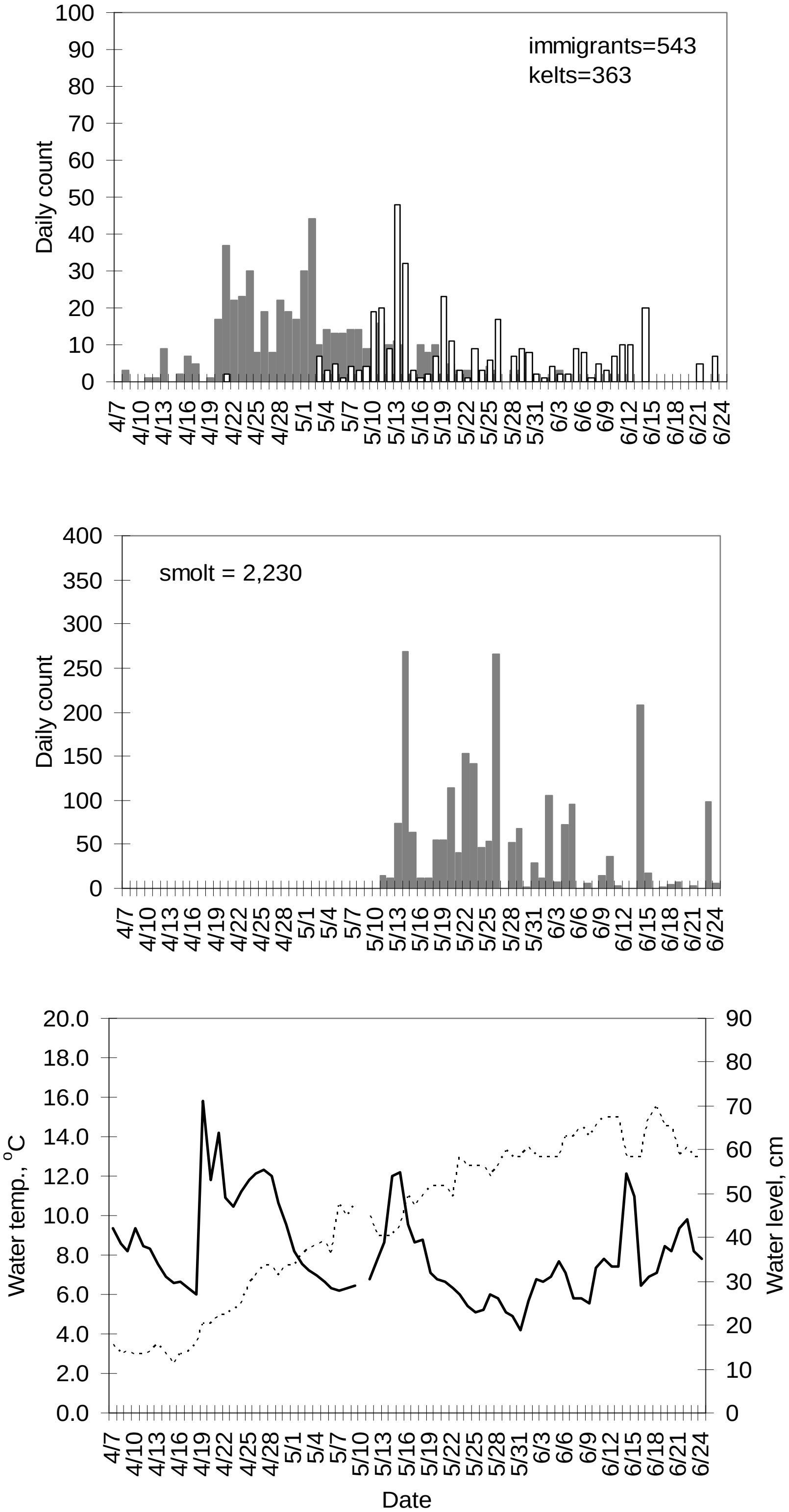


Figure 2.–Daily counts of immigrant steelhead (top panel solid bar graph) and kelts (top panel clear bar graph), emigrant steelhead smolt (center panel), and daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Sitkoh Creek, 2005 (bottom panel).

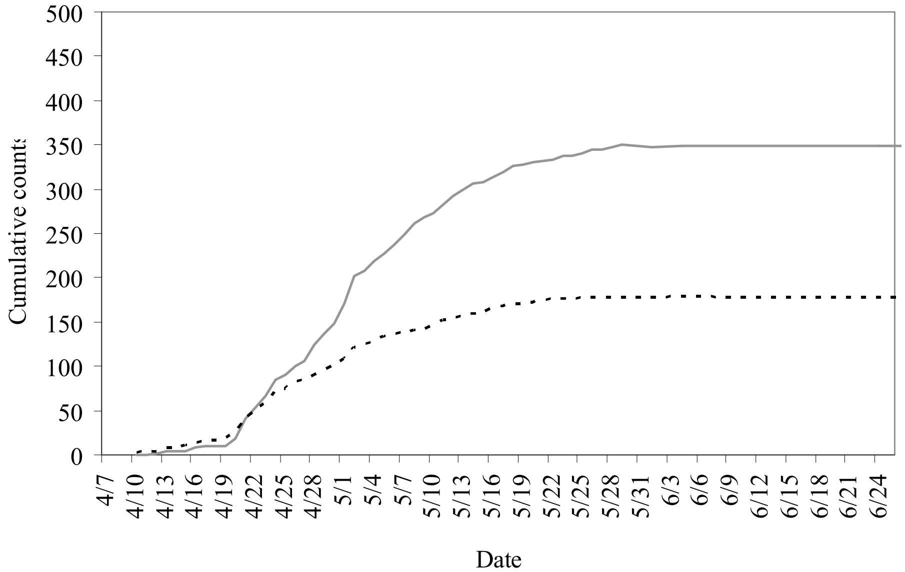


Figure 3.–Cumulative counts of adult male (stippled line) and female (solid line) steelhead immigrating through the Sitkoh Creek weir from 7 April to 25 June, 2005.

Steelhead Smolt

A total of 2,230 steelhead smolt and 26 juvenile (parr) steelhead were captured emigrating through the weir during 2005. Of these, 2,226 received a PIT tag and were released alive; there were two mortalities, one fish was not sampled due to excessive descaling, and one smolt had been previously tagged. The two mortalities equal about 0.09% (of the 2,230 smolt captured) of the total downstream migration. Paired scale and otolith samples were collected from both mortalities. The recaptured smolt had previously emigrated through Sitkoh weir on 2 June, 2004 at 181 mm FL and was recaptured in the downstream trap on 13 May, 2005 at 284 mm FL. It had physical characteristics similar to other emigrating smolt: parr marks and a silvery coloration. Of the 26 parr captured, one (143 mm FL) was PIT tagged, and the rest were released without being tagged.

The first smolt emigrant was captured at the weir on 11 May, the last on 23 June, and the midpoint of the run was 25 May. The peak daily count (269) occurred on 14 May and a similarly high count (266) occurred on 26 May (Figure 2). All but one of the steelhead smolt captured was measured and the mean length was 197 mm FL (SD = 27.7 mm, range 143 mm to 383 mm FL); the mode of the length frequency distribution was centered at 174 mm. The largest of the emigrants captured (>350 mm FL) had all the physical characteristics of average-sized smolt, so were regarded to be steelhead and not rainbow trout and were thus PIT tagged. Emigrant smolt that left Sitkoh Creek later in the season (after June 10th) were larger than earlier emigrants (Figure 5).

Scale samples were collected from 189 steelhead smolt (8.5%) and estimated freshwater ages based on visual analysis ranged from 3 to 6 years. Following aging protocol described earlier, most smolt (71%) were 3 or 4 years old, and most (55%) were 4 years old. Approximately 14% were age 5 and three fish were believed to have spent 6 years in freshwater prior to smolting. About 13% of the scale samples collected could not be read; they were either damaged or dirty, or had regenerated foci (Table 5). The largest smolt with readable scales measured 300 mm FL and was estimated to be 5 years old. Two larger smolt (360 and 383 mm FL) were sampled, but scale ages could not be estimated due to regenerated foci. The smolt that was recaptured in 2005 was not scale sampled in 2004 (Figure 6).

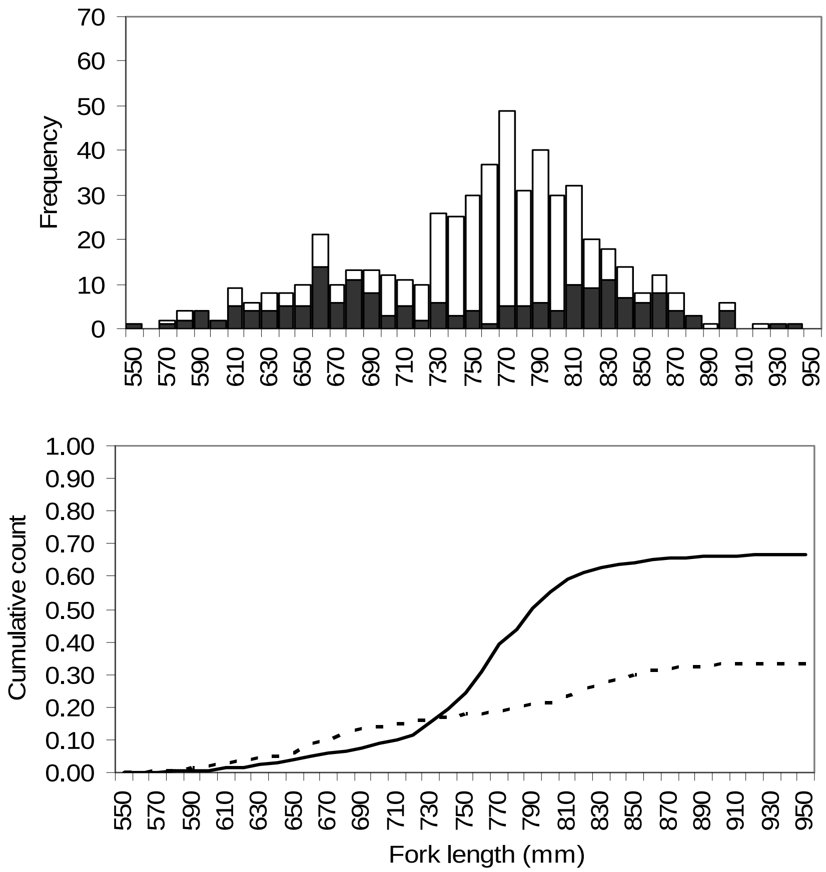


Figure 4.–Length-frequency distributions for male (filled bars) and female (clear bars) steelhead (top panel) and cumulative numbers by sex and length of adult male (stippled line) and female (solid line) steelhead immigrating into Sitkoh Creek during 2005 (bottom panel).

Table 3.–Proportion of the total steelhead escapement >914 mm TL, and proportion by sex for all fish >914 mm TL in years that a weir was operated. Data from Chipperfield (1938), Jones et al. (1991), Harding and Jones (1994), Yanusz (1997), Love and Harding (2008).

			Sex composition of steelhead ≥914 mm TL	
Year	No. of fish ≥914 mm TL[a]	Proportion of escapement ≥914 mm TL[a]	Proportion male (of fish ≥914 mm TL)	Proportion female (of fish ≥914 mm TL)
1982	48	0.070 [b]	0.380	0.620
1990	19	0.029 [b]	0.210	0.790
1993	29	0.056 [c]	0.530	0.470
1996	28	0.030 [b]	0.500	0.500
2003	16	0.024 [b]	0.875	0.125
2004	17	0.022 [b]	0.647	0.353
2005	13	0.024 [b]	0.692	0.308
2006	15	0.039 [b]	0.733	0.267

[a] 36 inches TL, assuming measurement error of 0.5 inches, the minimum size limit for sport harvest of steelhead in Southeast Alaska.

[b] All fish examined.

[c] Fish length sampled, SE=0.00091, N=303.

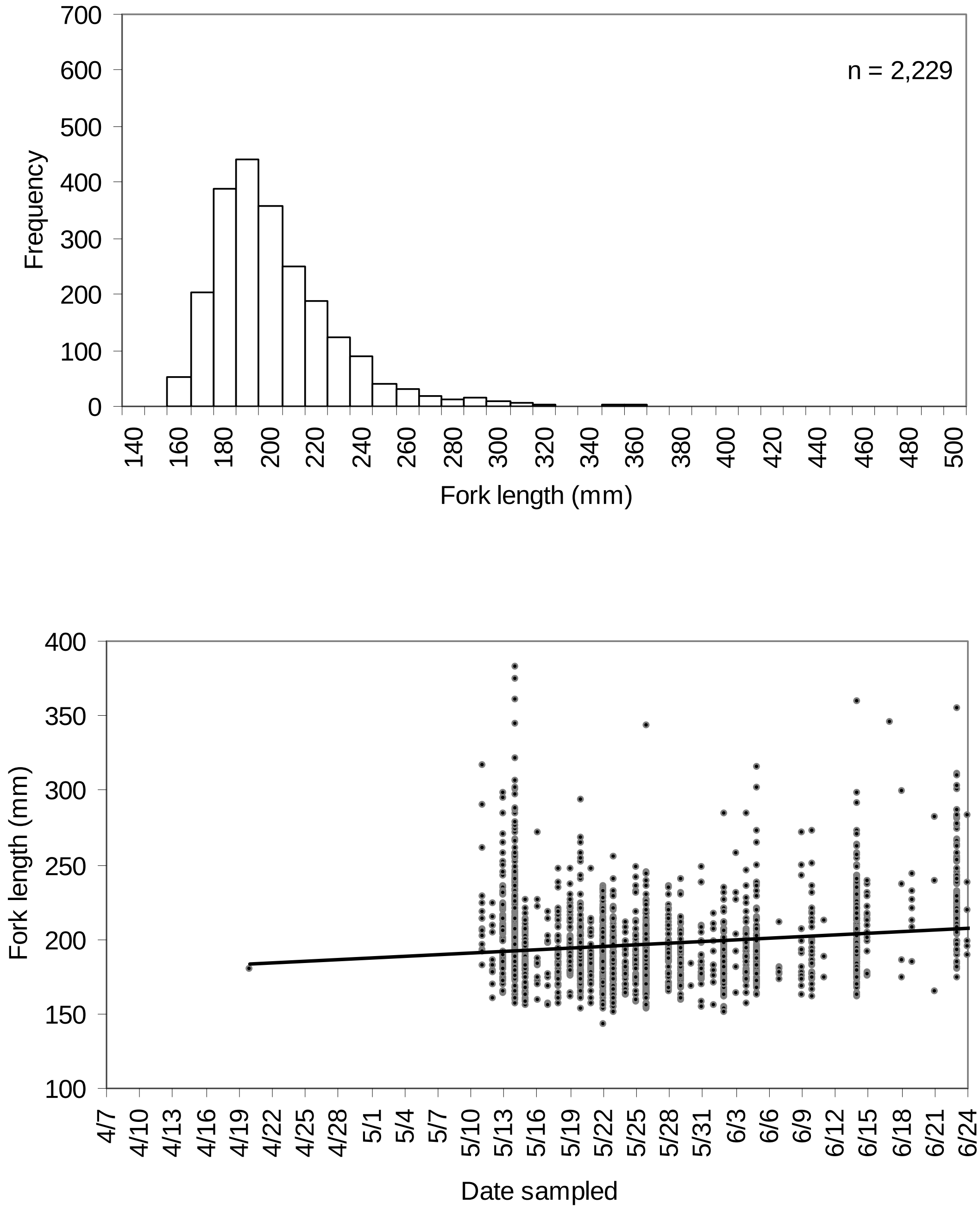


Figure 5.–Length-frequency distribution for steelhead smolt sampled emigrating out of Sitkoh Creek (top panel) and size (mm FL) of steelhead smolt by date captured at the weir during 2005 (bottom panel). Depicted trendline is the best fit linear trendline (y = mx + b) of smolt size by sample date (bottom panel).

Table 4.–Initial tagging year and number and percentage of adults recaptured during 2005 and 2006 in Sitkoh Creek.

	Recaptured adult year			
	2005		2006	
Tag year & type	*n*	%	*n*	%
2003 smolts	53	43.1	133	53.4
2004 smolts	0	0.0	49	19.7
2003 adults	9	2.3	1	0.4
2004 adults	56	45.5	27	10.8
2005 adults	-	-	35	14.1
Faulty tags	5	4.1	4	1.6

Table 5.–Freshwater ages based on scale analysis for Sitkoh Creek steelhead smolt, 2005 and 2006. Estimated ages based on three independent readings of a scale sample by the same scale-aging technician (total emigrant counts are in parenthesis).

	2005		2006		2005–2006	
Scale age	# Sampled	%	# Sampled	%	Total #	Avg %
Sample of total emigration	189 (2,230)	8.5	376 (3,550)	10.6	565 (5,780)	9.5
2	0	0.0	1	0.3	1	0.1
3	31	16.4	129	34.3	160	25.4
4	103	54.5	155	41.2	258	47.9
5	27	14.3	53	14.1	80	14.2
6	3	1.6	0	0	3	0.8
Unreadable	25	13.2	37	9.8	62	11.5
No match			14	3.7	14	1.9

Dolly Varden Char

There were 38,422 Dolly Varden emigrants captured and passed downstream through the weir. The first fish was captured on 12 April and the peak daily count (9,184) was on 13 May. The midpoint of the run occurred early in the day on 13 May (Figure 7). Dolly Varden were still being captured until the day before the weir was pulled (23 June). The subsample of those measured (n = 379) averaged 279 mm FL (SE = 3.1) and had SD of 61.2 mm; the emigrants ranged in length from 134 to 537 mm FL. The length distribution of emigrant Dolly Varden was essentially unimodal and the highest peak occurred within the 241–250 mm FL category; the mode was at 295 mm FL. Fork length generally decreased as the run progressed (Figure 8).

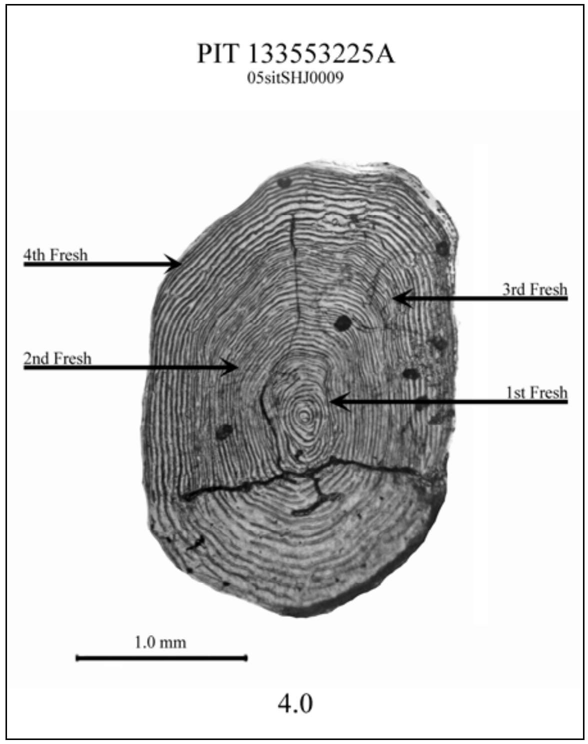


Figure 6.–Electronic scale image of scale sample taken from a repeat emigrant (re-emigrant) smolt recaptured in 2005 that was first tagged as an emigrant in 2004 (no scale sample taken). This fish would have been an age-3 freshwater smolt in 2004. Note the "estuarine" growth between the third and fourth annulus.

Cutthroat Trout

A total of 2,787 emigrant cutthroat trout were enumerated through the weir. The first trout was captured on 19 April and the midpoint occurred on 6 May. Emigrant cutthroat trout were still being caught in the downstream weir until the morning the weir was pulled (25 June). The peak daily count (199) occurred on 14 May, and another high count (193) occurred on 26 April (Figure 7). The fork length of those measured (n = 265) averaged 299 mm FL (SE = 3.7; SD = 60.0 mm) and ranged from 121 to 444 mm. The length distribution of emigrant cutthroat trout was somewhat bimodal, and the highest peak occurred within the 281–290 mm FL size category; another strong mode occurred at 221–230 mm FL. Many of the larger fish were in spawning condition and left the Sitkoh system early in the outmigration. The length of emigrants varied throughout the run, but generally fish length decreased through time (Figure 9).

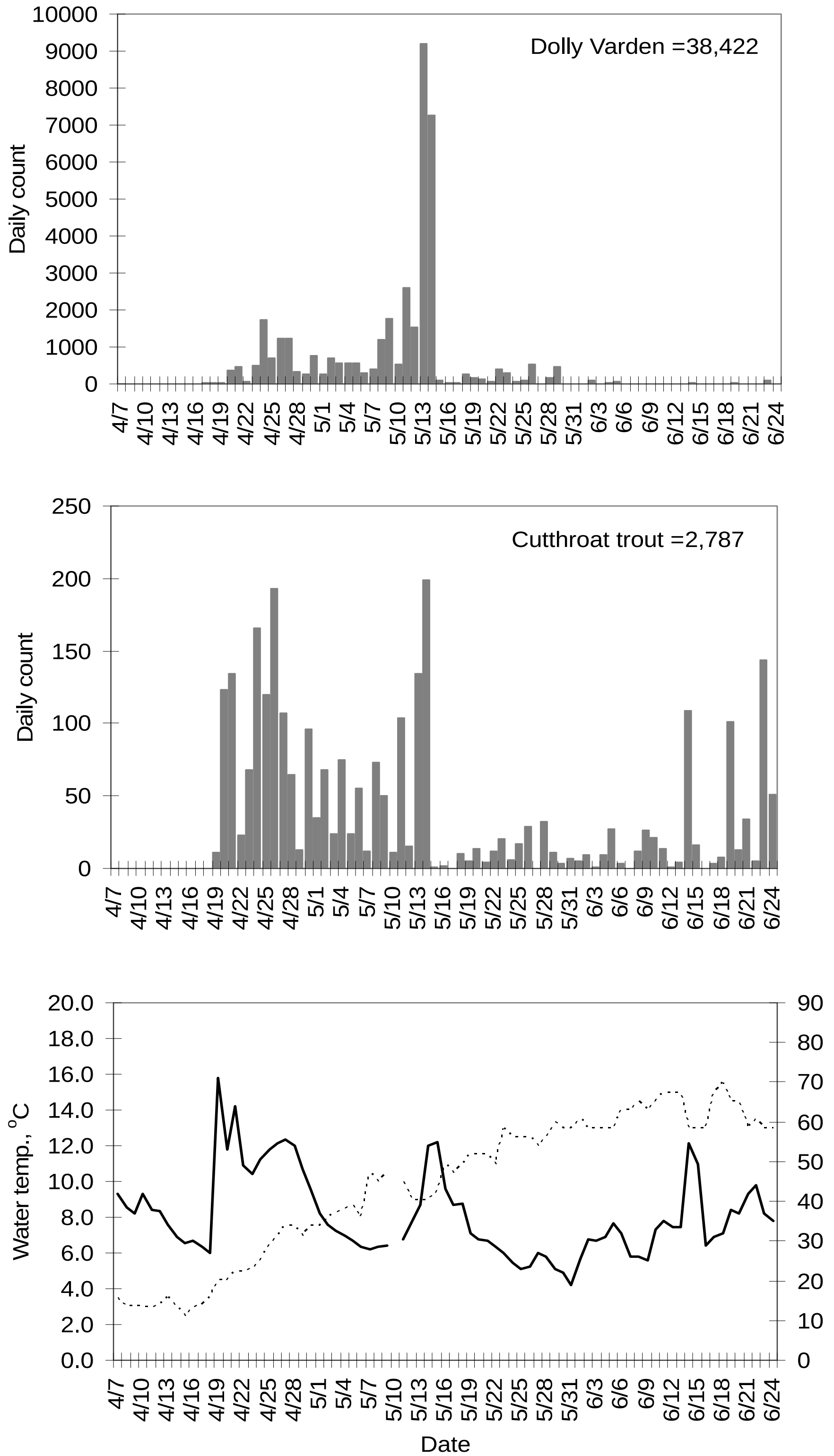


Figure 7.–Daily counts of emigrant Dolly Varden char (top panel), emigrant cutthroat trout (center panel), and daily measurements of water level in cm (solid line) and water temperature in °C (stippled line) at Sitkoh Creek, 2005 (bottom panel).

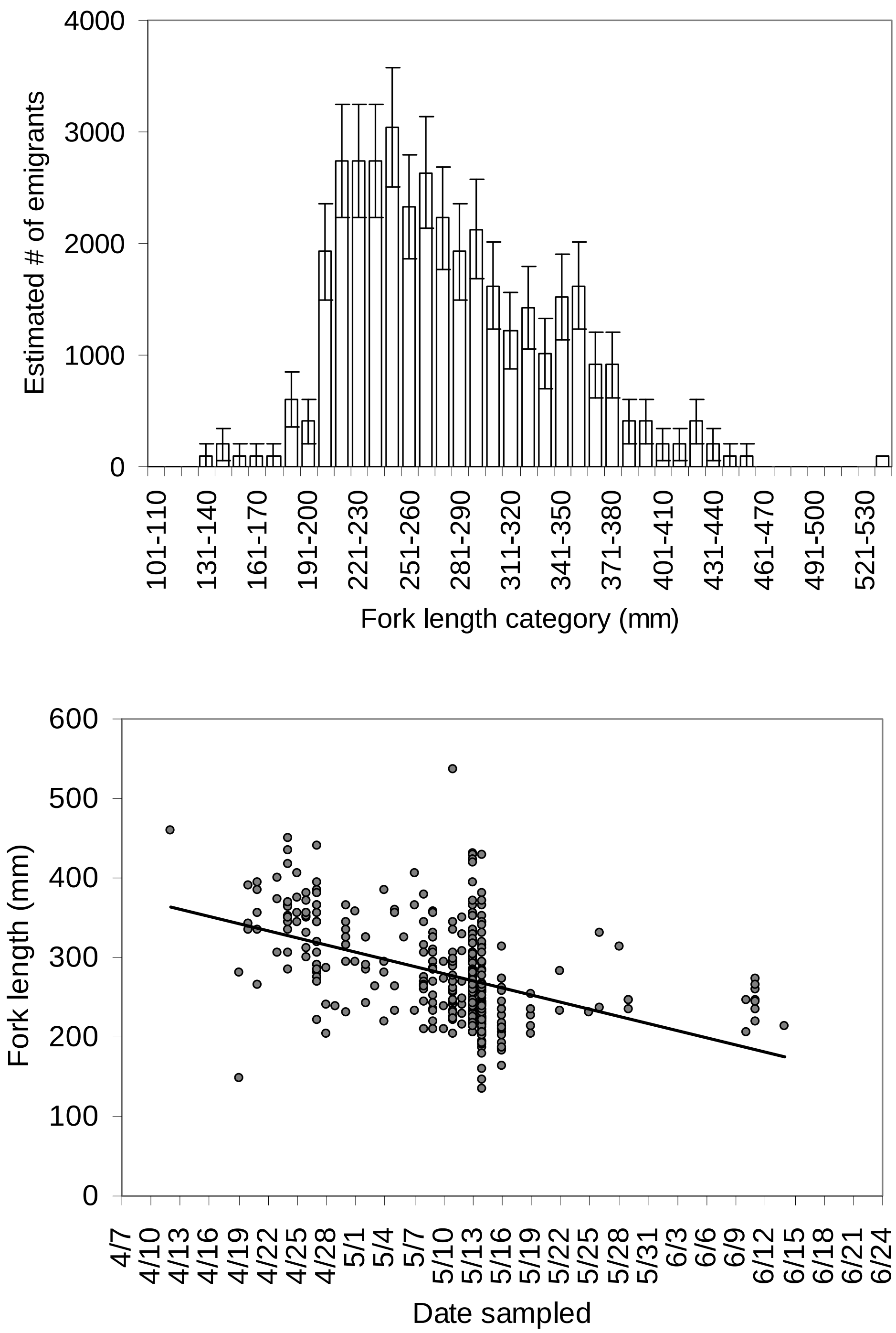


Figure 8.–Length-frequency distribution (top panel) and size at emigration (bottom panel) date for Dolly Varden char emigrating from Sitkoh Creek during 2005. Numbers are based on estimated proportions of emigrants by size category; sample standard error bars are ± one SE (379 Dolly Varden measured, 38,422 passed downstream through weir). The linear trendline (y = mx + b) of Dolly Varden size by sample date is depicted (bottom panel).

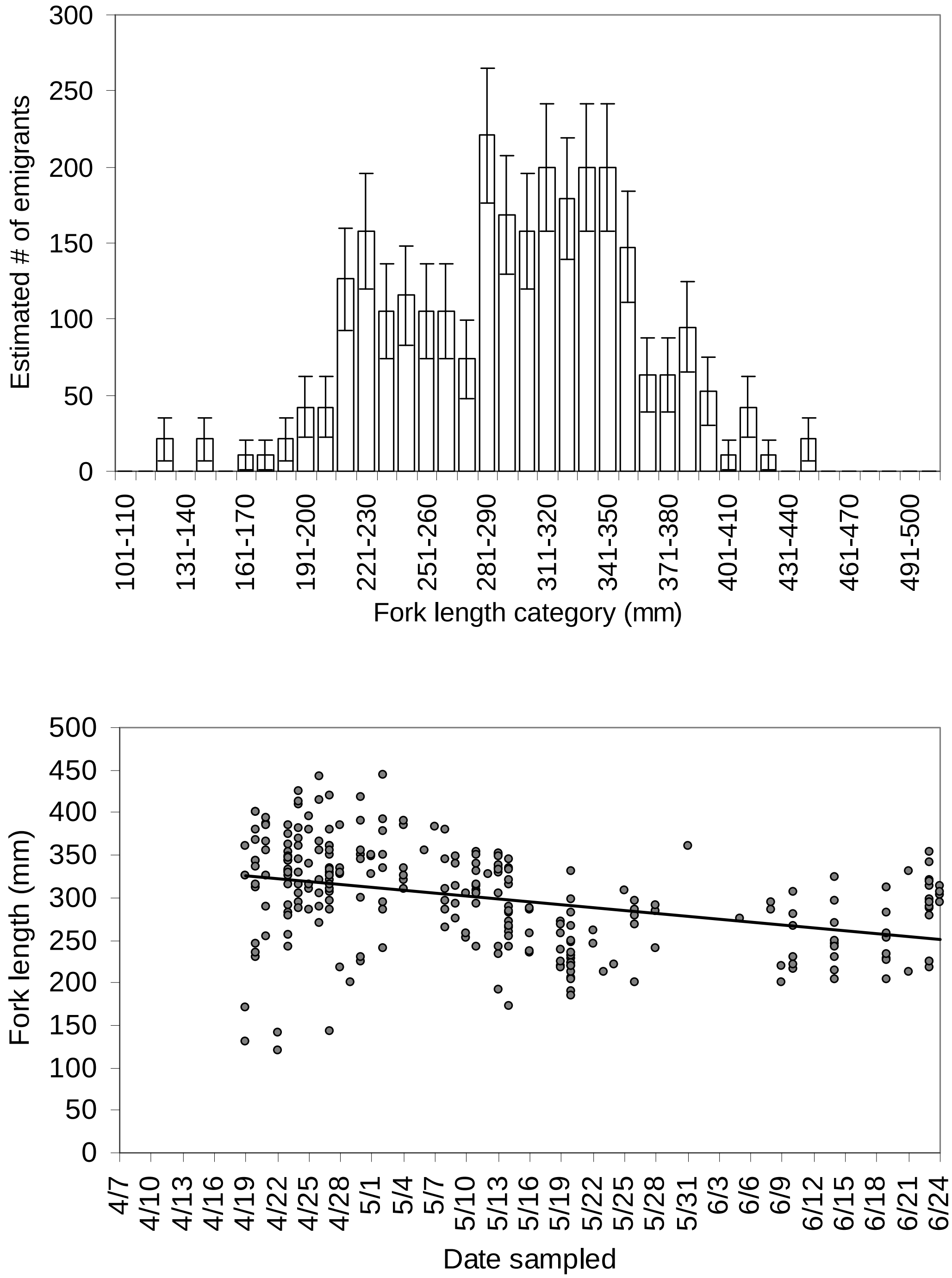


Figure 9.–Length-frequency distribution (top panel error bars are ± one SE) and size at emigration date (bottom panel) for cutthroat trout emigrating from Sitkoh Creek during 2005. Numbers are based on estimated proportions of emigrants by size category (265 cutthroat trout measured, 2,787 passed downstream through weir). The linear trendline (y = mx + b) of cutthroat trout size by sample date is depicted (bottom panel).

Other Migrants

Emigrant rainbow trout and rainbow/cutthroat trout hybrids, and immigrant sockeye salmon were also captured and passed through the Sitkoh Creek weir during 2005. There were nine rainbow trout emigrants passed downstream. There were also seven immigrant sockeye salmon that passed through the weir between 16 June and 24 June. No pink salmon were observed in 2005.

2006

Adult Steelhead–Immigration

The weir was continuously operated from 12 April to 24 June, 2006. The first adult steelhead immigrant was captured on 13 April, the day after the weir was fish tight. The last fish was captured on 18 June and the peak daily count (27) occurred on 20 May. The midpoint of the run was on 16 May (Figure 10). Water temperatures increased steadily from 3^{o} C on 12 April to almost 15^{o}C by 12 June.

A total of 395 adult steelhead immigrated into Sitkoh Creek in 2006. Of this total, 137 untagged fish and 249 previously-tagged fish were passed upstream through the weir, and 9 were untagged kelts passed downstream. The Chapman estimate for Sitkoh Creek adult steelhead abundance in 2006 was 416 (Bayesian SE = 3.5, 95% credibility interval = 409.1 to 422.9). Every untagged adult immigrant received a PIT tag and an adipose finclip. All untagged fish were measured, sexed, and PIT tagged while all recaptured fish were measured, sexed and the PIT tag number was recorded. Females made up 65% (257 fish) of the total immigration, while males represented 35% (138 fish, Table 1).

Scale samples were taken from 200 adults, or about 51% of the immigrant population. Based on scale aging analysis, an estimated 46.0% of the steelhead passing upstream through the weir were first-time spawners (Table 2). Eight age classes were documented among first-time spawners, with ages 4.3, 4.2 and 3.3 dominating at 11.0%, 10.5% and 10.0%, respectively. Age class x.3 was the next most abundant at 6.0% of all scale-sampled fish (n = 12). Three-ocean first-time spawners (55 fish, all freshwater ages combined) represented 27.5% of the immigration, while two-ocean first-time spawners in total (36 fish) represented 18.0% of the escapement. One 4-ocean, first-time spawner (0.5% of all scale sampled fish) was sampled in 2006. Repeat spawning fish returned to spawn 1–4 times; estimated saltwater ages ranged from 2 to 3 years, and freshwater ages from 2 to 5 before the first spawning event (see Figure 11 for an example of scales from a fish that spawned twice). Ocean ages were determined for all adults following analysis of scales sampled from recaptured fish of known age based on PIT tagging. Examples of known-aged digitized scales and aging methodology will be presented in future reports.

The length of immigrating steelhead averaged 749 mm FL and had SD = 73.2 mm (range = 548 to 923 mm). Proportionately fewer females than males immigrated into Sitkoh Creek prior to 8 May (Figure 12) and proportionately more fish >740 mm FL were females (Figure 13). The length of males averaged 743 mm FL and had SD = 88.8 mm (N = 143), and the length of females averaged 753 mm FL and had SD = 62.5 mm (N = 249).

Total length measurements from 392 fish were taken for inclusion in the regionwide regression model (Harding et al. 2009) and evaluation of current size-based regulations. In 2006, 15 fish (3.9% of the total immigrant steelhead run) met the minimum length requirements for sport fish retention (Table 3). Although more of the large fish in the 2006 escapement were females, proportionately more of the fish of legal size or greater (>914 mm FL or >36 in TL) were males (73.3%). In addition to length frequency measurements, spawning condition of 379 adult steelhead was recorded and categorized as bright (38%), semi-bright (16%), blush (43%), and undetermined condition (3%).

Of the total immigration, 63.0% (249) were recaptured fish that were initially PIT tagged as emigrant smolts or adults. Repeat spawning adults tagged in 2003, 2004 and 2005 as adults represented 0.4% (n = 1), 10.8% (n = 27) and 14.1% (n = 35) of the total recaptured fish, respectively (Table 4). Female repeat spawning adults outnumbered males about 3:1 for fish initially tagged as adults in 2004 and 2005. First time spawning adults (Table 4) initially tagged as smolts were either 2-ocean (19.7%, n = 49) or 3-ocean (53.4%, n = 133). Of the 2-ocean first time

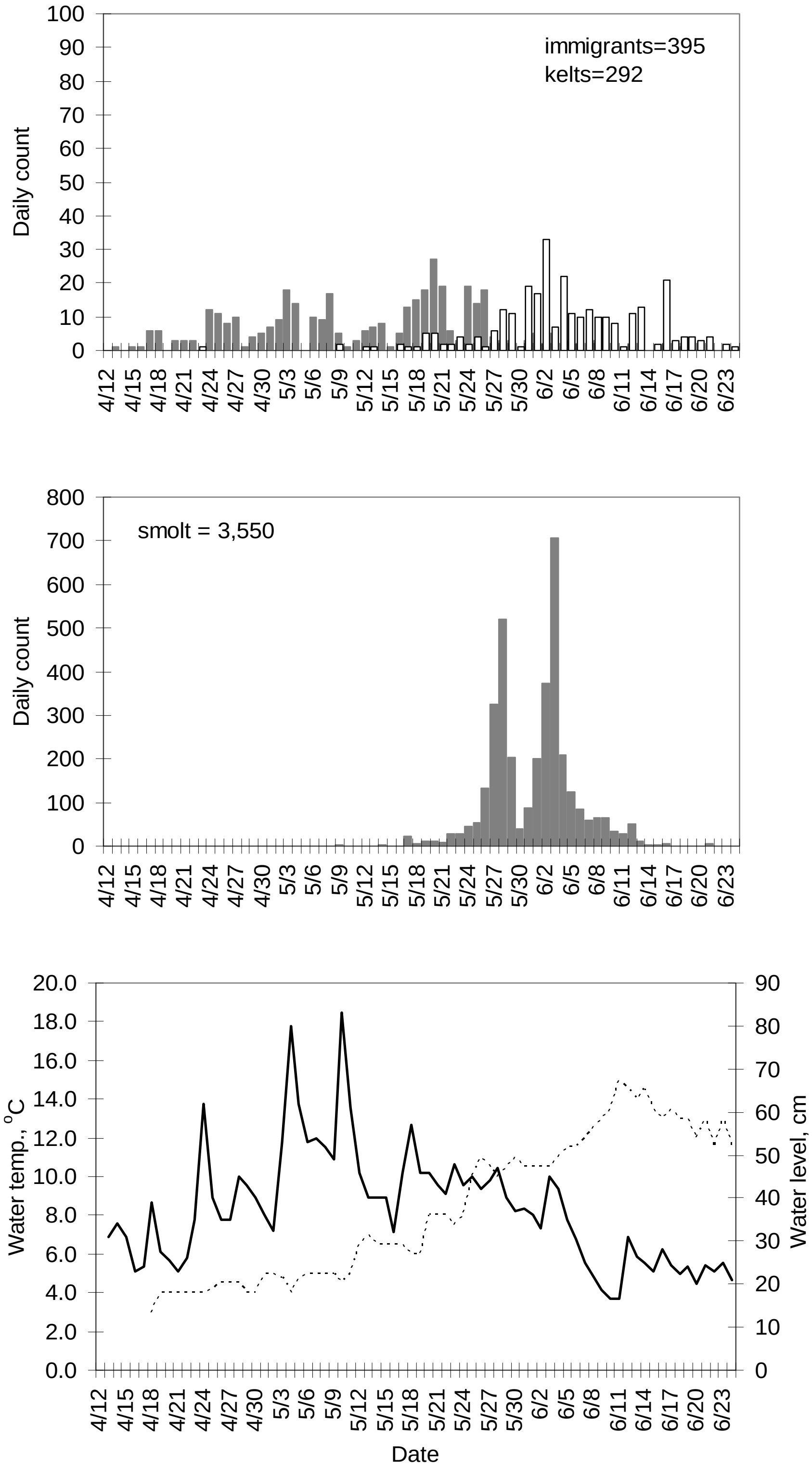
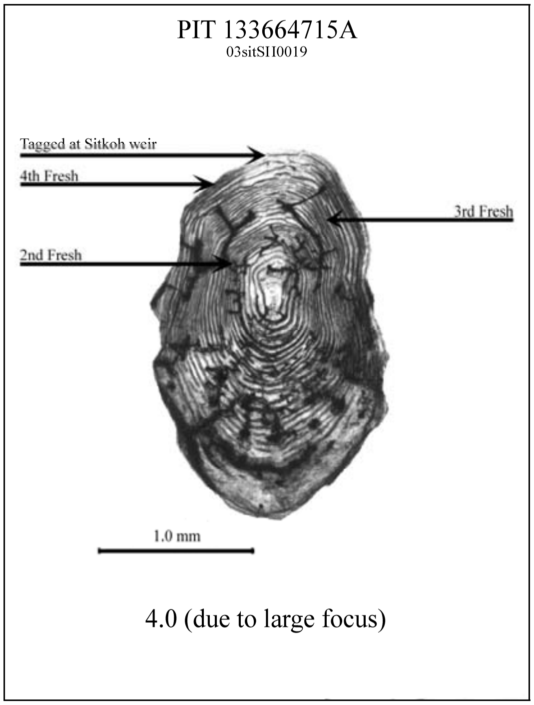
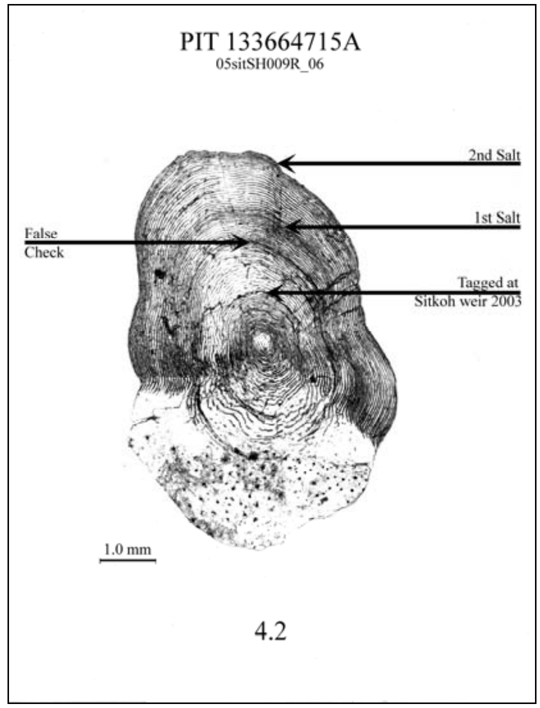


Figure 10.–Daily counts of adult upstream immigrant steelhead (top panel solid bar graph) and kelts (top panel clear bar graph), emigrant steelhead smolt (center panel), and daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Sitkoh Creek, 2006 (bottom panel).

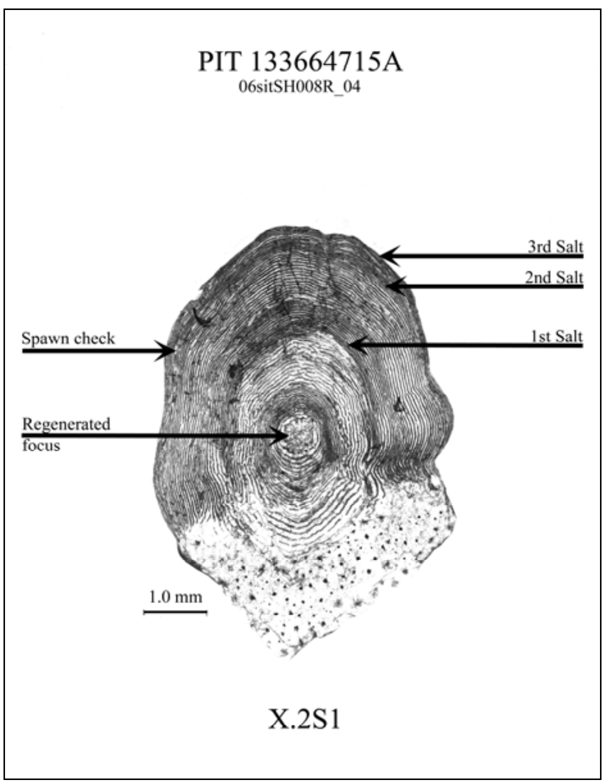


a)



b)

Figure 11.–Electronic scale images from scales sampled from steelhead smolt (freshwater age only) initially tagged in 2003 at Sitkoh Creek weir (a), recaptured as a first-time spawning adult in 2005 (b), and recaptured a second time as a repeat spawning adult in 2006 (c). Note the large, regenerated focus on the 2006 sample.



c)

spawners, nearly equal numbers of males (n = 25) and females (n = 24) returned. Of the 3-ocean spawners first time spawners, more females (n = 85) than males (n = 44) returned. Approximately 2% of the tags (four tags) were either faulty and could not be read, or did not match archived PIT tag numbers for Sitkoh Creek. The natal source stream and smolt emigrant year of the remaining 137 untagged adult fish was not known.

The length of all known repeat-spawning steelhead (n = 63) averaged 799 mm FL and had SD = 62.9 mm. The range was 658 to 923 mm. These fish grew an average of 46.7 mm per year and had a SD = 21.3 mm per year since initial tagging as adults in 2003, 2004 or 2005. The length of known repeat-spawning males measured averaged 793 mm FL and had SD = 76.6 mm (N = 15). Known repeat-spawning females averaged 800 mm FL and had SD = 19.0 mm (N = 48).

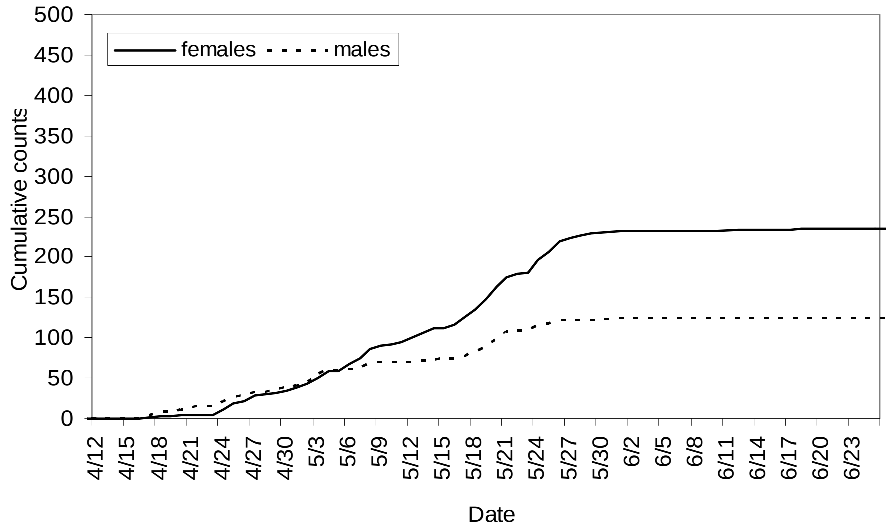


Figure 12.–Cumulative counts of adult male (stippled line) and female (solid line) steelhead immigrating through the Sitkoh Creek weir from 12 April to 24 June, 2006.

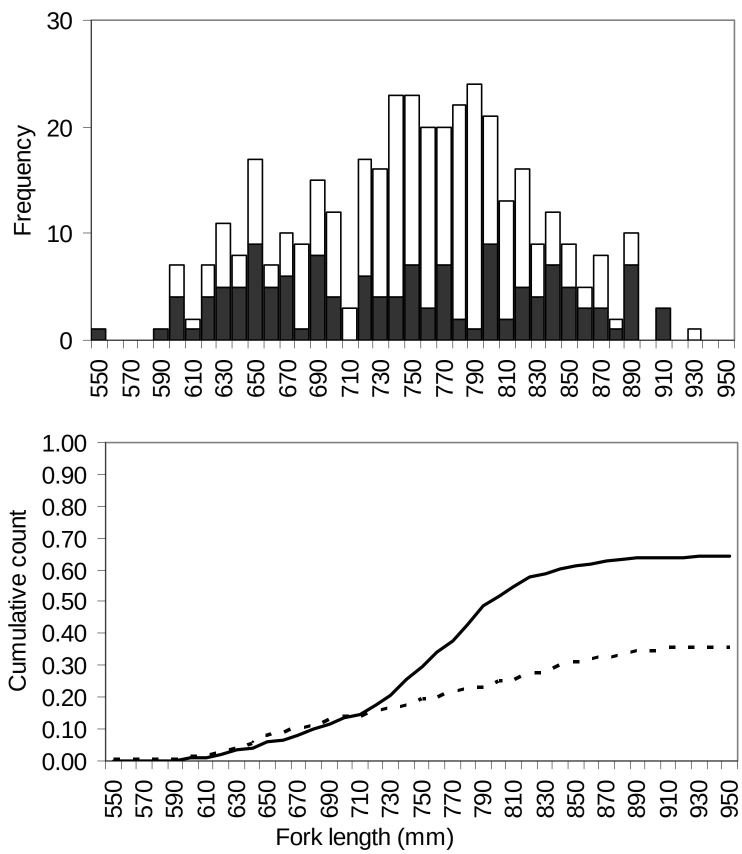


Figure 13.–Length-frequency distributions for male (filled bars) and female (clear bars) steelhead (top panel) and cumulative proportion by sex and length of adult male (stippled line) and female (solid line) steelhead immigrating into Sitkoh Creek during 2006 (bottom panel).

Adult Steelhead-Emigration

There were 295 adult steelhead captured emigrating from Sitkoh Creek in 2006. Of these, 286 had been previously marked during their upstream migration during either 2003, 2004, 2005 or 2006. There were nine untagged emigrants that must have immigrated prior to the weir being installed. All untagged fish were measured, sexed, PIT tagged and adipose finclipped prior to being released downstream. All untagged fish were males. Post-spawning survival was approximately 70.9% (295 emigrants/416 immigrants) in 2006.

The first kelt was captured on 23 April, the last was captured on 24 June, and the midpoint of the run was about 4 June. The peak daily downstream count (91) occurred on 2 June (Figure 10). The length of all measured emigrant steelhead averaged 749 mm FL and had a SD of 74.3 mm. The range was 600 to 923 mm (n = 277). Females varied less in size and were generally slightly larger than males. The length of females averaged 755 mm FL and had a SD of 63.7 mm, versus the length of males, which averaged 738 mm FL and had a SD of 93.4 mm. Proportionately more females (69.0%) emigrated from the system following spawning than did males, indicating that they survived spawning slightly better than did males.

Steelhead Smolt

A total of 3,561 steelhead smolt ≥150 mm FL emigrated through the weir in 2006, of which 3,549 were PIT-tagged, and released downstream; of these 3,544 were measured for FL. Twelve smolt were released untagged due to heavy descaling and poor condition. No juvenile steelhead (<150 mm FL) were noted moving downstream through the weir trap. The first steelhead smolt was captured emigrating through the weir on 1 May, and the last on 21 June. The midpoint of the emigration occurred about 1 June to 2 June and peak daily count (708 smolt) occurred on 3 June (Figure 10).

The length of steelhead smolt ≥150 mm averaged 219 mm FL and had SD = 39.1 mm (range = 110 to 420 mm). Emigrating steelhead smolt were slightly smaller in length later in the run (Figure 14). Scale samples were collected from 376 smolt (10.6% of the fish encountered). Preliminary scale analysis indicated that most smolt (76%) were estimated to be age 3 and 4, and ages ranged from age 2 to 6 (Table 5). About 12% of the scale samples collected could not be read due to large, regenerated foci, dirty scales, or an insufficient number of scales in the sample.

Dolly Varden Char

There were 29,820 Dolly Varden emigrants captured and passed downstream through the weir in 2006. The first fish was captured on 18 April, and the peak daily count (4,455) occurred on 17 May (Figure 15), which was also the midpoint of the run. One in 98 Dolly Varden were measured during 2006. The lengths of those measured (n = 304) averaged 272 mm FL (SE = 3.7) and had a SD of 64.3 mm. Fish ranged in size from 136 to 484 mm FL. The length distribution of emigrant Dolly Varden was essentially unimodal. The mode was at 265 mm and the median at 268 mm FL. Fork length generally decreased as the run progressed (Figure 16).

Cutthroat Trout

A total of 2,491 emigrant cutthroat trout were enumerated through the weir. The first trout was captured on 17 April, and the midpoint of the weir count occurred on about 9 May. The highest daily count (250) occurred on 3 May (Figure 15). One in ten fish were measured for FL. Cutthroat lengths averaged 310 mm FL (SE = 4.2) and had a SD = 65.6 mm. Fish ranged in size from 174 to 443 mm FL. The length distribution of emigrant cutthroat trout appears to be somewhat bi-modal with a mode at 201 to 210 mm FL and another mode at 341 to 350 mm. The median values for the cutthroat lengths measured in 2006 equaled 331 mm FL. Many of the larger fish were in spawning condition and left the Sitkoh system earlier in the spring. Average size generally decreased with time (Figure 17).

Other Migrants

During weir operations in 2006, 41 rainbow trout were passed downstream. These fish were believed to be the stream-resident form of coastal rainbow trout (Behnke 2002) that may have been migrating between the freshwater and nearshore estuarine systems. The average length of emigrant rainbows was 262 mm FL (SE = 15.3) and had a

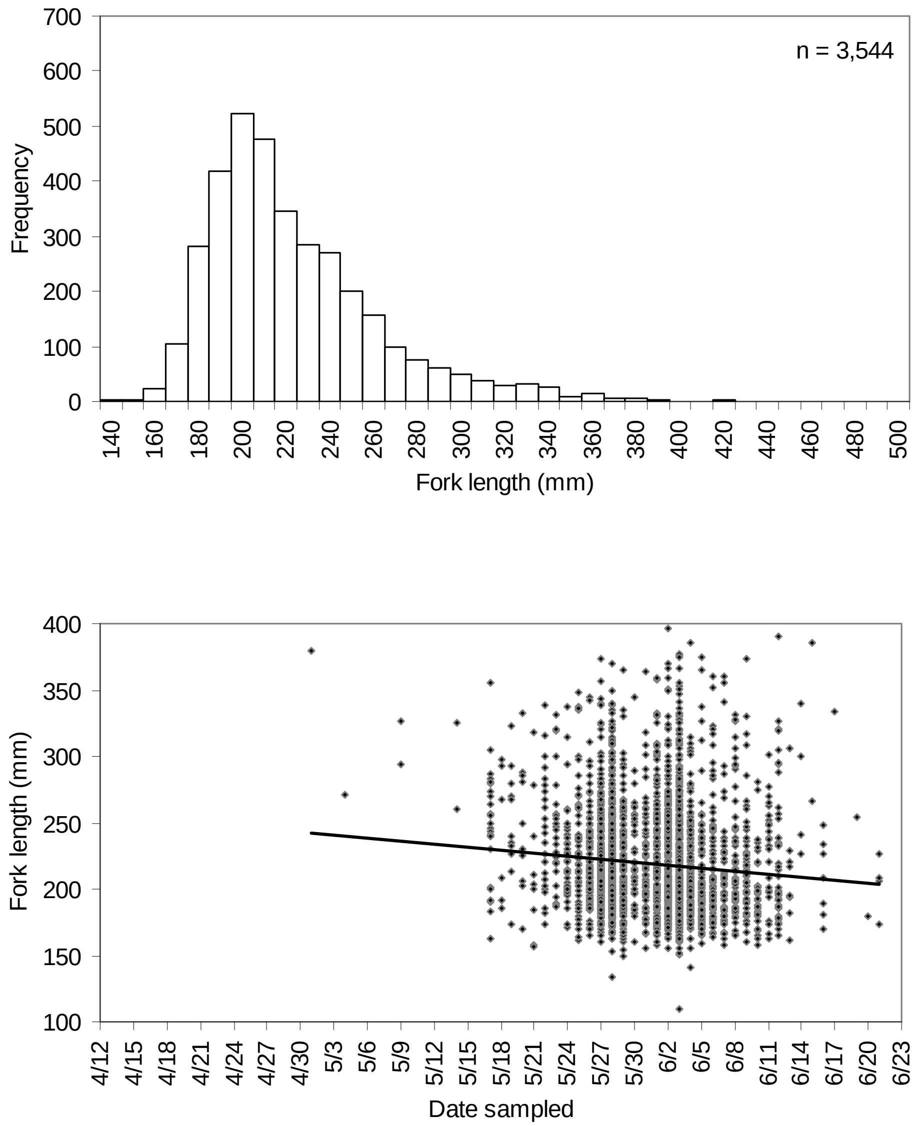


Figure 14.–Length-frequency distribution for steelhead smolt sampled emigrating out of Sitkoh Creek (top panel) and size (mm FL) of steelhead smolt by date captured at the weir during 2006. The linear trendline (y = mx + b) of smolt size by sample date is depicted (bottom panel).

SD = 97.8; lengths ranged from 140 to 436 mm FL. Only four sockeye salmon were captured migrating upstream from 20 June to 22 June, and no pink salmon were passed prior to removal of the weir.

DISCUSSION

The biological parameters investigated during this study provide resource managers a short time series of data from a steelhead system in northern Southeast Alaska that supports moderate sport fishing pressure. Few long-term (10 years or greater) steelhead smolt-adult time series have been collected from streams on the West Coast. Previous long-term studies include the Keogh River on Vancouver Island (Ward and Slaney 1988), Waddell Creek in California (Shapovalof and Taft 1954), Snow Creek in Washington (Johnson and Cooper *in* Bley and Moring 1988), and in the Columbia and Snake River drainages. Within coastal Alaska, multi-year escapement

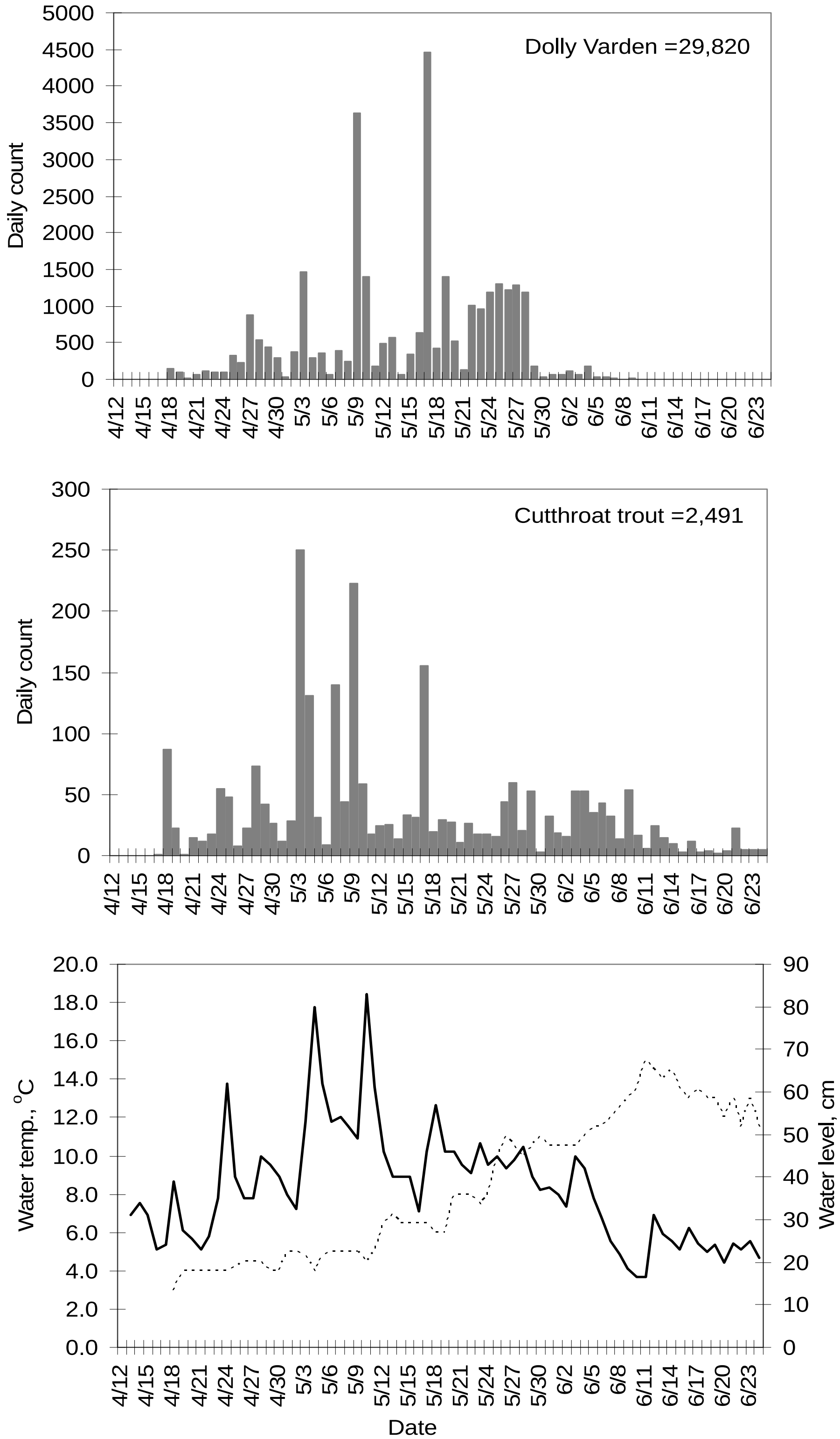


Figure 15.–Daily counts of emigrant Dolly Varden char (top panel) and emigrant cutthroat trout (center panel), and daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Sitkoh Creek, 2006 (bottom panel).

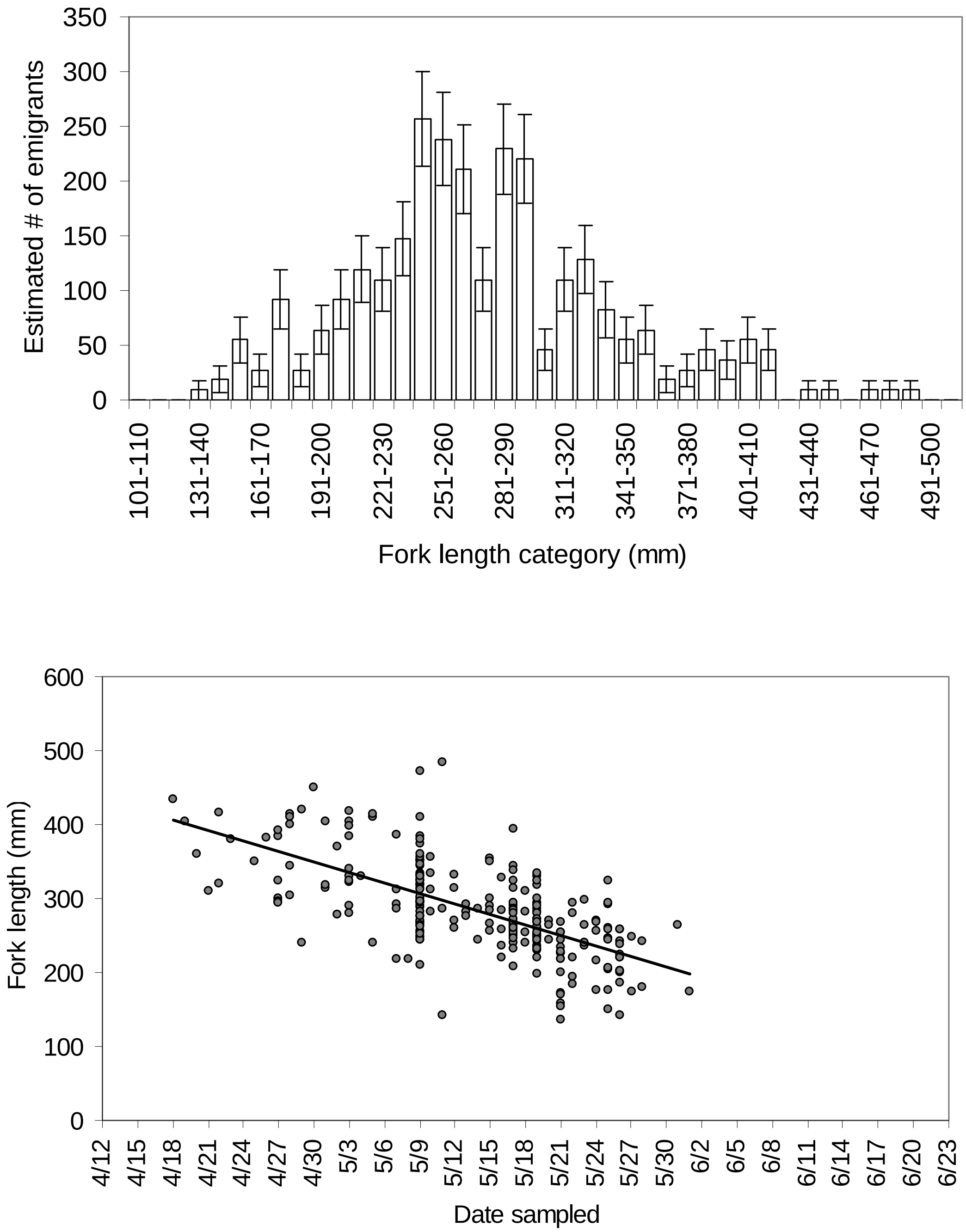


Figure 16.–Length-frequency distribution (top panel error bars are ± one SE) and size at emigration date for Dolly Varden char (bottom panel) emigrating from Sitkoh Creek during 2006. The linear trendline (y = mx + b) of Dolly Varden size by sample date is depicted (bottom panel). Numbers are based on estimated proportions of emigrants by size category (304 Dolly Varden measured, 29,820 passed downstream through weir).

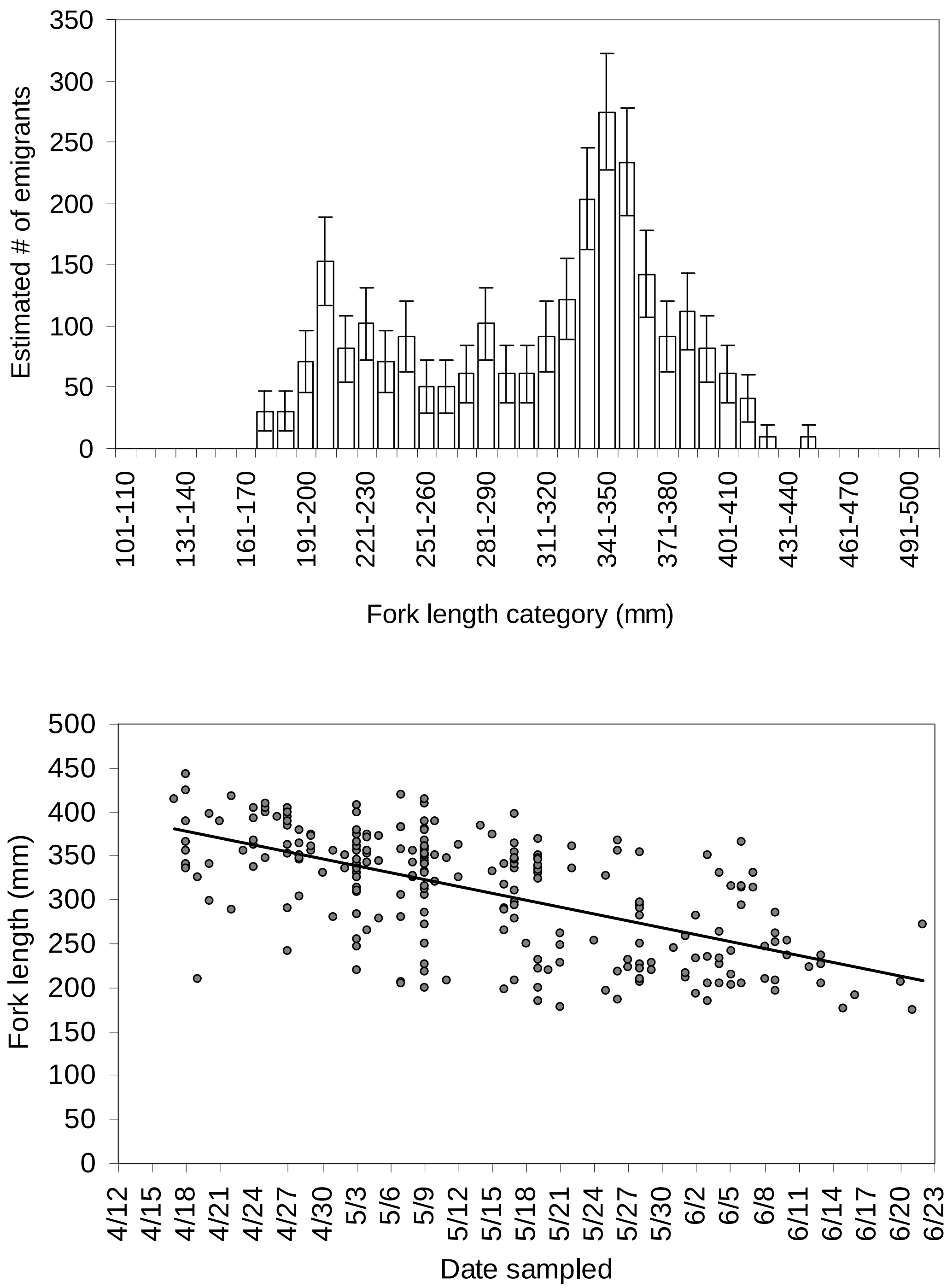


Figure 17.–Length-frequency distribution (top panel error bars are ± one SE) and size at emigration date for cutthroat trout emigrating from Sitkoh Creek during 2006 (bottom panel). Numbers are based on estimated proportions of emigrants by size category (245 cutthroat trout measured, 2,491 passed downstream through weir). The linear trendline (y = mx + b) of cutthroat trout size by sample date depicted in lower panel (bottom panel).

and/or creel studies (5 years or less) have been conducted on the Anchor, Karluk, Karta, and Situk rivers, as well as on Petersburg, Petersen and Sitkoh creeks (Lohr and Bryant 1999; Freeman and Hoffman 1989-91; Harding and Jones 1990-1994). Long-term tagging data from a relatively unperturbed stream system in Southeast Alaska have not been available. Most previous PIT-tag research was only related to movement of smolt through the hydroelectric dams in the Columbia River Basin, or ocean migrations of hatchery smolt and adults in and around the north Pacific. This project is unique in Alaska, and possibly throughout their native range, in that no other long-term studies of a wild steelhead population have used PIT-tagging techniques to estimate adult and smolt production, migration timing, survival rates, and freshwater and ocean ages. Continued study at Sitkoh Creek may enable researchers to estimate smolt-to-adult ocean ages and survival and adult-to-smolt production. Baseline information such as that presented below may be useful for management action following future changes to regulations, use, or harvest.

ADULT PRODUCTION, SIZES, SEX RATIOS AND SURVIVAL

The total number of adult steelhead immigrants during 2005 and 2006 were nearly as low as, or below all escapement counts made for Sitkoh Creek since 1936 (Table 1). Weir integrity was not compromised during 2005 and 2006, thus counts were considered a census of spring steelhead migrations into and out of Sitkoh Creek for April to June each year. It is not known if these low counts indicate declines in production, but subsequent escapement counts on Sitkoh Creek will provide more information on interannual variability.

The proportion of female immigrants during 2005 and 2006 was higher than males and is consistent with 2003 and 2004. This trend has been observed in previous years in Sitkoh Creek, other Alaska and Southeast Alaska streams, and in other West Coast systems. Proportionately more females composed the total immigration in Sitkoh Creek during all of the first 4 years of the study: 67% in 2005 and 65% in 2006, and 62% in 2003 and 60% in 2004 (Love and Harding 2008). Proportionately more females (56 to 65%) than males have been reported in the spawning runs of four other Southeast Alaska systems: Karta River, Petersburg Creek, Peterson Creek, Situk River, (Lohr and Bryant 1999). Proportionately more females than males have also been reported in the following Southcentral and Gulf area streams in Alaska: Anchor River, Karluk River, Copper River, Crooked Creek and Nikolai Creeks (Wallis et al. 1984; Begich 1999; Gates and Palmer 2006a-b; Wuttig et al. 2004) and in the Columbia River Basin (Holubetz 1995).

The average fork length of female steelhead in 2005 and 2006 was greater than the average fork length of males. The length frequency distribution of adult steelhead in Sitkoh Creek in 2005 could be considered bimodal with males centered around the smaller mode, and larger females predominant at the larger mode (Figure 4); in 2006 the length frequency distribution appeared to be more unimodal (Figure 13). Females, on average, were larger than males during all 4 years, and have also been reported to be larger than males in other systems including: Karta River, Petersburg Creek, Peterson Creek, Situk River, Anchor River, Karluk River, Crooked Creek and Nikolai Creek (Lohr and Bryant 1999; Gates and Palmer 2006a-b).

Female adult steelhead appeared to survive spawning better than males in 2005 and 2006. Female kelts composed 63% of all kelts in 2005 and 69% in 2006, compared to immigration sex compositions of 66% in 2005 and 69% in 2006. Post spawning females also appeared to have higher survival rates in the Karta River, Petersburg Creek, Peterson Creek, Situk River, Anchor River and Karluk River during the 1971 to 1993 period (Lohr and Bryant 1999), the Keogh River in 1988 (Ward and Slaney 1988) and in Crooked and Nikolai creeks in 2005 and 2006 (Gates and Palmer 2006a-b).

PIT-tagged recaptures corroborated demographic measures in the overall escapement: females were older, more abundant, survived spawning at higher rates, spent less time in freshwater, and were larger. In 2006, approximately the same number of 2-ocean males (51%) and 2-ocean females (49%) returned to spawn, but 3-ocean females that spawned for the first time were more abundant (64%). In 2005, the survival of first-time spawning males was lower (44%) than first-time spawning females (68%). In 2006, more first-time spawning females survived to emigrate (77%) than did males (50%). Post-spawning survival of female steelhead appears to be higher in Sitkoh Creek than in the Keogh River, where higher survivals also lead to a higher incidence of repeat-spawning in females (Ward and Slaney 1988). Recapture of previously tagged adults indicated repeat spawning females were on average larger than males in both 2005 and 2006; mean FL of females was 735 (SD = 67.9) and 737 (SD = 61.1) mm vs. the length of males 674 (SD = 60.2) and 698 (SD=66.5). Female immigrants were also more abundant; female to male sex ratios were 1.7:1 and 3.2:1 in 2005 and 2006, respectively. In the Keogh River, females repeat-spawned more than males and females were also more abundant as kelts. This may be attributed to females leaving the system soon after spawning, whereas males remain longer to engage in multiple spawning attempts (Shapovalof and Taft 1954; Withler 1966). This also seems to be the case for Sitkoh Creek: during 2004 males spent 39 days on average in the stream, while females spent 26 (Love and Harding 2008); in 2005 males spent 31 while females spent 21 days; and in 2006 males spent 36 and females spent 21 days.

ADULT IMMIGRATION TIMING

The timing of steelhead immigration at Sitkoh Creek during 2005 was very similar to observations from weir counts in the 1980s to 2004 (Jones et al. 1991; Harding and Jones 1994; Yanusz 1997; Love and Harding 2008). The midpoint of the immigration occurred on 30 April in 2005. In 2006, the midpoint of immigration occurred on 15 May, later than other years, but similar to that reported in the historical data from 1936 and 1937 (Jones et al. 1991; Chipperfield 1938; Figure 18). Immigration timing at Sitkoh Creek appears to be intermediate between steelhead systems to the north and south. In southern Southeast Alaska, the midpoint of steelhead immigration in Big Ratz Creek and Harris River on Prince of Wales Island occurred on 26 April, 2005 and 15 April, 2005, respectively (Piazza et al. 2008). The midpoint of steelhead migration in Eagle Creek was 10 May, 2006 and in Cable Creek was 26 April, 2006 (Piazza 2009). Farther to the north in the Situk River, the midpoint occurred on 18 May in 2005 and 30 May in 2006 (Bob Johnson, ADG&G, Division of Sport Fish, personal communication).

Annual peaks in adult immigration between 2003 and 2006 appeared to follow high flow events (Figures 2 and 10). In both 2005 and 2006, peak immigration appeared to lag slightly behind the highest spring floods. Adult steelhead remained in the system 20 to 30+ days then left as water temperatures increased and spring flows decreased. Above average snowfall (37.8 inches above normal) during the winter months of 2006 took longer to completely melt, keeping water temperatures lower through the spring and possibly delaying immigration by about 2 weeks (National Weather Service Forecast Office in Juneau 2007[2]). Although water temperature and flow data were unavailable for the 1936 and 1937 weir projects on Sitkoh Creek, the 1936 written summary indicated slow snow melt and little rainfall. This may indicate that the snowpack was greater and the spring season was colder, possibly resulting in a protracted immigration period (Banta 1936, 1937) as was also seen in 2006 (Figure 18). The heavy snowfall experienced by the Southeast Alaska region in 2006 appears to have delayed immigration into Situk River and the Prince of Wales Island streams as well (Bob Johnson and Kelly Piazza, ADF&G, Division of Sport Fish, personal communication). Although immigration was delayed and escapement numbers in Sitkoh Creek were lower in 2006, snorkel survey counts in other streams elsewhere in Southeast Alaska were at least average, and some counts higher than average (Harding 2008). Chilcote (2008) found that by including environmental indices such as snow pack in Beverton-Holt models, the models better described variations in steelhead recruitment for 26 streams in Oregon. Although it is not clear that Southeast Alaska steelhead streams have benefitted from high snowfall, using environmental variables such as annual snowpack to model recruitment may be useful.

[2] Climate Report for 2006, product identifier CXAK57 PAJK. http://pajk.arh.noaa.gov/ (accessed January 2009).

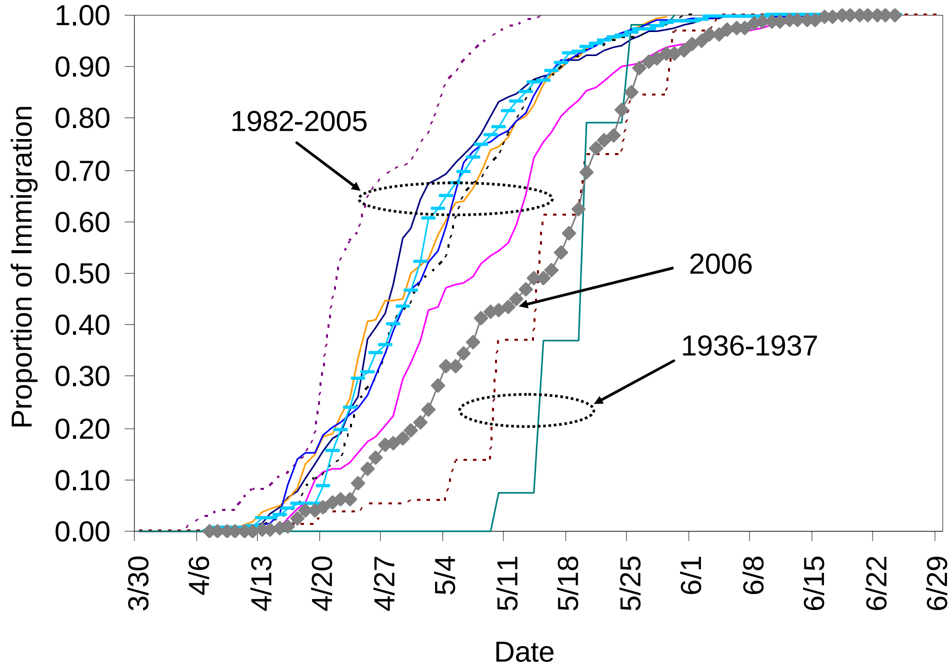


Figure 18.–Immigration timing of steelhead at Sitkoh Creek for all years during which a weir was operated showing shift in immigration timing between historic and recent years. Data from Chipperfield (1938), Jones (1983), Jones et al. (1991), Harding and Jones (1994), Love and Harding (2008), and Yanusz (1997).

LEGAL SPORT FISH SIZES AND MANAGEMENT ISSUES

Although females were proportionately more abundant overall, the sex composition of very large steelhead (>914 mm TL or ≥36 in TL) was mostly males (69% in 2005 and 73% in 2006). Prior to 2003, sex ratios of legal-sized fish were more equal or skewed towards females (Table 3). Since 2003, sex ratios of the largest fish (legal size) have been skewed towards males. Nonetheless, only 13 and 15 fish (2.4 to 3.9% of the escapement on average) were available for legal harvest during 2005 and 2006, respectively.

The current conservative regulations appear to be providing sustainability of the Sitkoh Creek steelhead stocks while allowing for a limited harvest opportunity. It is not known whether Sitkoh Creek steelhead are captured in any subsistence or commercial fisheries as no tags have been recovered; however Sitkoh steelhead have been observed to stray into other streams. During a snorkel survey of Sitkoh River on 18 May, 2006, located at the head of Sitkoh Bay about 2.5 km northwest of Sitkoh Creek, six adipose-clipped steelhead adults out of a total of 50 fish counted were observed in a 2 mile section of the river. This is the first indication of straying of Sitkoh Creek fish outside their natal stream.

STEELHEAD SMOLT PRODUCTION AND LENGTHS

Smolt size and abundance appeared to be relatively similar year-to-year during the 2003–2006 period. The steelhead smolt emigration counts in 2005 (N = 2,230) and 2006 (N = 3,561) were comparable to the emigration counts in 1996 (N = 3,883), 2003 (N = 3,166) and 2004 (N = 3,742) counts, but less than the average of 3,597 smolts for these 3 years (Yanusz 1997; Love and Harding 2008). During both 2005 and 2006 the smolt length distributions were unimodal, averaged about 200–210 mm FL, ranged from 110 to 420 mm, and were similar to that observed during 2003 and 2004 (196–200 mm FL average, 40–385 mm range, Love and Harding 2008).

From 2003 to 2006, Sitkoh Creek smolt were larger and had a wider ranging length distribution than reported for the Keogh River in British Columbia in 1993 (173 mm FL, range 160 to 187 mm). Subsequent smolt sizes for the Keogh averaged 171 mm in 2002 and 180 mm in 2003, smaller than in Sitkoh Creek (McCubbing 2002; McCubbing and Ward 2003). Keogh River results for the 2004–2006 period are not available. As suggested by previous decade-long Keogh River research, adult run size and age structure appeared to vary directly with smolt abundance and body size, which influenced ocean survival (Ward and Slaney 1988, 1993; Ward et al. 1989). The average length of 2003 outmigrant smolts that returned as adults in 2005 and 2006 (average = 196 mm FL, SD = 24.7) was not different than the mean length of all 2003 outmigrant smolts (average = 200 mm FL, SD = of 24.7). Although size-associated survival seems to influence adult returns at Keogh River, smolt size and abundance at Sitkoh Creek during the last 4 years has not varied enough to describe the relationship to adult survival.

SMOLT AGING, SURVIVAL, AND SMOLT PER SPAWNER

Initial estimates of ocean survival based on PIT-tagged smolts returning to Sitkoh Creek to spawn for the first time in 2005 and 2006 were generated using the 2003 and 2004 smolt emigration. In 2005, 53 (43%, Table 4) of all recaptured fish were first tagged as smolts in 2003 (2-ocean returns). In 2006, 133 (53%) were 3-ocean fish tagged as smolts in 2003 and returning as first-spawning adults. Also in 2006, 49 (20%) fish were 2-ocean adults first tagged as smolts in 2004. Based on these tagging returns, 5.9% of the 2003 smolt emigration (186 of 3,166) survived to return as adults in 2005 and 2006; counts of returning 2003 smolts in 2007 and 2008 should allow the first complete estimate of smolt-to-adult survival from Sitkoh Creek. No smolt tagged during 2003 were recaptured in 2004 as ocean age 1. No ocean-age-1 smolt (2004 or 2005 PIT-tagged smolt) were recaptured during either 2005 or 2006. Although sample size of returning tagged fish is small (n = 186), marine survival estimates for smolts to adults compares favorably with Keogh River during 2002 to 2003, which ranged from 4.5% to 7.8% based on scale aging (Ward and Slaney 1988; McCubbing 2002; McCubbing and Ward 2003).

A high proportion of steelhead smolt (73% of all scale-sampled fish) in Sitkoh Creek appeared to be freshwater ages 3 and 4 during both 2005 and 2006 (Table 5). Compared to estimated smolt ages from the Keogh River from 1977 to 1983, Sitkoh Creek smolt were older during the 2003–2006 period (Ward and Slaney 1988; Love and Harding 2008). Approximately 89% of Keogh River smolt averaged 2 to 3+ freshwater age and fewer (11%) were aged 4+ (Ward and Slaney 1988). This may not be unexpected as steelhead may spend more years in freshwater before smolting in northern streams (Withler 1966). In 2005, no scale-sampled smolts were aged as 2 freshwater. In 2006, 1 fish (0.3%) of all fish that were aged was estimated to be 2 years old. In 2006, 129 scales were aged as 3 freshwater (34.4%), originating from the 2003 adult brood class. Extrapolating using the total smolt outmigration in 2006 and the 2003 escapement, a partial estimate of smolt per spawner of 1.8 smolts can be calculated. Assuming that the scale aging process produces an unbiased, consistent estimate of age, the freshwater-age-4 and -5 smolt scale samples collected in 2007 and 2008 should further define the estimated smolt-per-spawner estimate for the 2003 brood class based on scale analysis. Samples taken in 2009 will allow calculation of a complete second smolt-per-spawner estimate for the 2004 adult brood class.

RAINBOW TROUT LIFE HISTORY AND EMIGRATION

Small numbers of rainbow trout emigrated through the Sitkoh weir during 2005 and 2006. Early in the season, many of these fish were classified as ripe as they readily released milt and eggs when handled. It is not known if these fish were migrating to other stream systems to spawn, as documented for cutthroat trout from Sitkoh Creek (Yanusz 1997; Jones and Yanusz 1998), or migrating within the system. However, there is very little if any spawning habitat between the weir and saltwater, i.e., the substrate is predominately cobble on bedrock. Some of the later rainbow emigrants appeared to be in postspawning condition (fungus, abraded pelvic and caudal fins) and may have been moving into the estuary to recover and possibly feed. One "re-emigrant" smolt initially tagged in 2004 was recaptured in 2005. Examination of scale samples collected from this second-time emigrant showed increased spacing of the circuli, or growth, near the outer margin of the scale and suggested this fish may have spent time after its initial emigration in richer estuarine feeding areas. This post-emigration behavior more closely resembles that of sea-run cutthroat trout (Jones and Seifert 1997; Jones and Yanusz 1998). This "re-emigrant" smolt was not in spawning condition. "Re-emigrant" steelhead smolt were also captured in 2004 at the Sitkoh weir, indicating that a small percentage of the fish in this population have life history strategies similar to the "half-pounder" form described by Behnke (2002). Behnke describes a life history form of rainbow trout where smolts may enter marine waters during the spring months, return to freshwater during late summer and fall, and smolt again the following spring to reside in the ocean and grow into adult steelhead. It also may be possible that these fish are sea-run rainbow trout, similar in behavior to the classic sea-run cutthroat trout form, i.e., fish that migrate during the spring and summer between fresh and estuarine waters, eventually entering other stream systems to spawn, followed by overwintering in freshwater. Life history polymorphism of rainbow and steelhead trout observed at Sitkoh may allow for a greater variety of genetic diversity to be conserved if conditions change and may confer greater survival to the species as a whole (McEwan et al. 2005; Jonsson and Jonsson 1993; Shapovalof and Taft 1954).

DOLLY VARDEN CHAR PRODUCTION, EMIGRATON, AND LENGTH

The number of Dolly Varden emigrants in 2005 (38,422 fish) and 2006 (29,820 fish) were both below emigrant counts in 2003 (52,884) and 2004 (62,409). More than half (54%) of the total 2005 emigration occurred during 11 May to 15 May, whereas pulses of emigrating fish passed the weir during 2006 and about half (49.3%) of the emigration occurred between 3 May and 28 May (Figures 7 and 15). Emigration pulses occurred during or immediately following rainfall and high water events during 2005 and 2006. Heavy early flows and warming water temperature seemed to stimulate large numbers of fish to emigrate in mid May 2005. The mean length of emigrant Dolly Varden in 2005 (278 mm FL) was nearly the same as in 2006 (276 mm FL), and the mean lengths and size ranges in both years were similar to 2003 and 2004 (Love and Harding 2008).

CUTTHROAT TROUT PRODUCTION, EMIGRATION, AND LENGTH

The cutthroat trout emigrations in Sitkoh Creek during 2005 (2,787) and 2006 (2,491) were lower than the mean emigrant count for 1996, 2003 and 2004 (4,213). The 2005 and 2006 counts may be incomplete as fish were still being counted downstream through the weir up until the day the weir was removed. The timing of the cutthroat trout emigration in 2005 appeared to be similar to that observed in 2006 (Figures 7 and 13). Emigration timing in 1996 and 2003 appeared to be similar, while in 2004 it was completed almost 2 weeks earlier (Love and Harding 2008; Yanusz 1997). Even though emigrant counts were lower in 2005 and 2006, emigrant weir counts of overwintering cutthroat trout at Sitkoh Creek were still relatively high in comparison to other Southeast Alaska systems (Yanusz 1997).

The range of cutthroat trout lengths sampled as they passed through the weir in 2005 and 2006 were comparable to previous years, but there were fewer fish < 240 mm FL fish passing the weir in 2005 and 2006 than in 1996, 2003 and 2004 (Figures 9 and 17; Yanusz 1997; Love and Harding 2008). Coupled with emigration of larger fish, this has resulted in increased mean length during these years (299 mm FL, SE = 3.6 in 2005; 310 mm Fl in 2006, SE = 4.2 in 2006).

OTHER SPECIES

Salmon species co-occurring in the same stream may benefit steelhead juveniles, e.g., abundant and healthy stocks of sockeye salmon may contribute a ready food supply of eggs, thus supporting consistently healthy, genetically diverse populations of steelhead, as well as cutthroat trout and Dolly Varden char (Wright 2004). Few immigrant sockeye salmon into Sitkoh Creek were counted during 2005 and 2006. However, mark–recapture estimates of sockeye escapement for Sitkoh lake indicated strong returns for both years: 13,400 spawners in 2005 and 14,800 in 2006 (Burril and Conitz. 2007; Conitz and Burril 2008). Low flow levels and high water temperatures in 2004 may have prevented sockeye spawners from reaching Sitkoh Lake to spawn, which could have had unknown consequences on steelhead juvenile survival and growth. Only 3,700 sockeye were estimated to have reached the lake in the fall of 2004, less than a third of the average of the previous 5 years escapement estimates (Conitz and Cartwright 2007). Other egg predators such as cutthroat trout and Dolly Varden char may also have suffered, although the reason for the lower numbers emigrating through the weir in 2005 and 2006 is unknown. The presence of other salmon species in the Sitkoh Creek system may confer additional feeding advantage to steelhead fry and parr. Marine-derived nutrients transported into freshwater systems contribute a large amount of energy needed for growth of resident rainbow in streams draining the Lake Nerka part of the Wood River system in Bristol Bay (Scheuerell et al. 2007). Differences in steelhead smolt production in odd versus even years in the Keogh River may be a function of pink salmon egg deposition during critical freshwater rearing stages of steelhead juveniles (Ward et al. 1989). Although no pink salmon were counted through the weir into Sitkoh Creek during 2005 and 2006, Sitkoh Creek supports a healthy pink salmon run that enters the creek later in the summer. Higher steelhead production in lake versus stream systems in Southeast Alaska may be due to more consistent salmon production in these systems as well.

ACKNOWLEDGMENTS

Dale Brandenburger was the field crew leader for both years. Lee Close, Rich Didrickson and Dirk Middleton were the field crews. Roger Harding and John Der Hovanisian provided support in all aspects of the project, from operational planning to editing and reviewing the manuscript. Kurt Kondzela, Peter Bangs, Ryan Briscoe, Carrie Hoover, Judy Lum, Jarrod Sowa, Keith Pahlke, Jason Shull, Shawn Johnson, Jennifer Stahl, Raymond Vinzant, and Rocky Holmes assisted with camp operations as well as mobilization and de-mobilization. Randy Mullen and Dan Reed provided biometric support during the study design, development of the operational plan, and manuscript review. Special thanks go to Bob Chadwick and Linda Schmidt for providing logistical support for the project and to Anne Chadwick for home-cooked lasagna for the crews. Judy Shuler prepared the manuscript for publication.

REFERENCES CITED

Banta, G. 1936. Research on Dolly Varden trout, Sitkoh Bay, Alaska, from April 17 to May 31, 1936. Unpublished report located at: USDA, Forest Service, Juneau.

Banta, G. 1937. Report on Dolly Varden trout research, Sitkoh Bay, Alaska, March 11, 1937 to May 31,1937. Unpublished report located at: USDA, Forest Service, Juneau.

Begich, R. N. 1999. Population ecology of adult steelhead trout (*Oncoryhnchus mykiss*) of the Karluk River, Alaska. Master's thesis, University of Idaho.

Behnke, R. J. 2002. Trout and salmon of North America. The Free Press, New York, New York.

Bley, P. W., and J. R. Moring. 1988. Freshwater and ocean survival of Atlantic salmon and steelhead: a synopsis. U.S. Fish and Wildlife Service Biological Report 88 (9):1-22.

Burril, S. E., and J. M. Conitz. 2007. Kanalku and Sitkoh Lakes subsistence sockeye salmon project: 2005 annual report. Alaska Department of Fish and Game, Fishery Data Series No. 07-68, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds07-68.pdf

Carlin, B. P., and T. A. Louis. 2000. Bayes and empirical Bayes methods for data analysis. 2nd edition. Chapman & Hall/CRC., New York.

Chilcote, M. 2008. Assessing the impact of climate change on steelhead viability based on a new linkage between mountain snowpack and recruitment performance. Eleventh Pacific Coast Steelhead Management Meeting, March 4-6, 2008. Pacific States Marine Fishery Commission and US Fish and Wildlife Service. http://www.psmfc.org/steelhead2008/

Chipperfield, W. A. 1938. Report on Dolly Varden trout research, Sitkoh Bay stream. Unpublished report located at: USDA-Forest Service, Juneau.

REFERENCES CITED (Continued)

Conitz, J. M., and S. E. Burril. 2008. Kanalku and Sitkoh Lakes subsistence sockeye salmon project: 2006 annual report. Alaska Department of Fish and Game, Fishery Data Series No. 08-29, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds08-29.pdf

Conitz, J. M., and M. A. Cartwright. 2007. Kanalku and Sitkoh Lakes subsistence sockeye salmon project: 2004 annual report. Alaska Department of Fish and Game, Fishery Data Series No. 07-01, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds07-01.pdf

Crupi, A., J. Nichols, B. Frenette, and R. Harding. *In prep*. Steelhead habitat capability study, Phase I/II: Habitat characterization/fish use on Sitkoh Creek. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Ericksen, R. P. 1999. Scale aging manual for coastal cutthroat trout from Southeast Alaska. Alaska Department of Fish and Game, Special Publication No. 99-4, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/sp99-04.pdf

Freeman, G. M., and S. H. Hoffman. 1989. Steelhead *Oncorhynchus mykiss* creel census on the Klawock River, southeast Alaska, 1987-1988. Alaska Department of Fish and Game, Fishery Data Series No. 118, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds-118.pdf

Freeman, G. M., and S. H. Hoffman. 1990. Steelhead *Oncorhynchus mykiss* creel census and recreation survey on the Thorne River, southeast Alaska, 1988-89. Alaska Department of Fish and Game, Fishery Data Series No. 90-34, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds90-34.pdf

Freeman, G. M., and S. H. Hoffman. 1991. Thorne River steelhead creel and recreation survey, 1989-1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-30, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds91-30.pdf

Gates, K. S., and D. E. Palmer. 2006a. Abundance and run timing of adult steelhead trout in Crooked and Nikolai Creeks, Kenai Peninsula, Alaska, 2005. Alaska Fisheries Data Series Number 2006-5, March U.S. Fish and Wildlife Service.

Gates, K. S., and D. E. Palmer. 2006b. Abundance and run timing of adult steelhead trout in Crooked and Nikolai Creeks, Kenai Peninsula, Alaska, 2006. Alaska Fisheries Data Series Number 2006-13, November 2006, U.S. Fish and Wildlife Service.

Harding, R., and J. D. Jones. 1990. Peterson Creek and lake system steelhead evaluation, 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-37, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds90-37.pdf

Harding, R., and J. D. Jones. 1991. Peterson Creek and Lake system steelhead evaluation, 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-31, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds91-31.pdf

Harding, R., and J. D. Jones. 1992. Peterson Creek and Lake system steelhead evaluation, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-46, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds92-46.pdf

Harding, R., and J. D. Jones. 1993. Karta River steelhead: 1992 escapement and creel survey studies. Alaska Department of Fish and Game, Fishery Data Series No. 93-30, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds93-30.pdf

Harding, R., and J. D. Jones. 1994. Sitkoh creek steelhead: 1993 escapement and harvest. Alaska Department of Fish and Game, Fishery Data Series No. 94-36, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds94-36.pdf

Harding, R. D., and D. C. Love. 2008. Southeast Alaska steelhead snorkel surveys of regional index streams, 2004 and 2005. Alaska Department of Fish and Game, Fishery Data Series No. 08-19, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds08-19.pdf

Harding, R. D., K. A. Kondzela, and R. P. Marshall. 2009. Survey of anglers using Southeast Alaska recreational cabins during 2006. Alaska Department of Fish and Game, Fishery Data Series No. 09-60, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/FDS09-60.pdf

REFERENCES CITED (Continued)

Holubetz, T. B. 1995. Wild steelhead studies, 1993 annual report. Idaho Department of Fish and Game, Annual Report (Report Number 91-073) to Bonneville Power Administration, Portland, Oregon.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001a. Revised Edition. Harvest, catch, and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-25 (revised), Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds98-25(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001b. Revised Edition. Participation, catch, and harvest in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-41 (revised), Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds99-41(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001c. Participation, catch, and harvest in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series No. 01-08, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds01-08.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2007. Participation, catch, and harvest in Alaska sport fisheries during 2004. Alaska Department of Fish and Game, Fishery Data Series No. 07-40, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds07-40.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2009a. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2005. Alaska Department of Fish and Game, Fishery Data Series No. 09-47, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/FDS09-47.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2009b. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2006. Alaska Department of Fish and Game, Fishery Data Series No. 09-54, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/FDS09-54.pdf

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2004. Participation, catch, and harvest in Alaska sport fisheries during 2001. Alaska Department of Fish and Game, Fishery Data Series No. 04-11, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds04-11.pdf

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006a. Participation, catch, and harvest in Alaska sport fisheries during 2002. Alaska Department of Fish and Game, Fishery Data Series No. 06-34, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/fds06-34.pdf

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006b. Participation, catch, and harvest in Alaska sport fisheries during 2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-44, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/fds06-44.pdf

Jones, D. E. 1983. Steelhead investigations in Southeast Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project AFS-42, 24 (AFS-42-10-A), Juneau.

Jones, D. E. Undated/Unpublished. Handbook for interpretation of steelhead trout scales in Southeast Alaska. Available through ADF&G SF Region 1 Douglas, Alaska, USA.

Jones, J. D., R. Harding, and A. Schmidt. 1991. Sitkoh Creek steelhead study, 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-32, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds91-32.pdf

Jones, J. D., and C. L. Seifert. 1997. Distribution of mature sea-run cutthroat trout overwintering in Auke Lake and Lake Eva in Southeastern Alaska [*in*] J. D. Hall, P. A. Bisson, and R. E. Gresswell, editors. Sea-Run Cutthroat trout: biology, management, and future conservation. Oregon Chapter, American Fisheries Society, Corvallis.

Jones, J. D., and R. Yanusz. 1998. Distribution of mature sea-run cutthroat trout from Sitkoh Creek, Alaska in 1996. Alaska Department of Fish and Game, Fishery Data Series No. 98-17, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds98-17.pdf

Jonsson, B., and N. Jonsson. 1993. Partial migration: niche shift versus sexual maturation in fishes. Reviews in Fish Biology and Fisheries 3:348-365.

Lohr, S. C., and M. D. Bryant. 1999. Biological characteristics and population status of steelhead (Oncorhynchus mykiss) in southeast Alaska. General Technical Report PNW-GTR-407. U.S Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Love, D. C., and R. D. Harding. 2008. Steelhead trout production studies at Sitkoh Creek, Alaska, 2003–2004. Alaska Department of Fish and Game, Fishery Data Series No. 08-44, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds08-44.pdf

McCubbing, D. J. F. 2002. Adult steelhead trout and salmonid smolt migration at the Keogh River, B.C. During winter and spring 2002. Province of British Columbia Habitat Conservation Trust Fund Contract No.CBIO3006.

McCubbing, D. J. F., and B. R. Ward. 2003. Adult steelhead trout and salmonid smolt migration at the Keogh River, B.C. during spring 2003. Province of British Columbia Habitat Conservation Trust Fund Contract No. CBIO4051.

McEwan, D., K. Perry, and M. Lacy. 2005. The rainbow trout-steelhead debate, continued. The Osprey, Federation of Fly Fishers, Issue No. 50, Bozeman, MT.

Piazza, K. S. 2009. Assessment of Adult Steelhead Populations on Prince of Wales Island, Alaska: Eagle Creek and Cable Creek, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 09-14, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds09-14.pdf

Piazza, K. S., G. K. Chen, and R. Mullen. 2008. Assessment of adult steelhead populations on Prince of Wales Island, Alaska: Harris River and Big Ratz Creek, 2005. Alaska Department of Fish and Game, Fishery Data Series No. 08-46, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/fds08-46.pdf

Scheuerell, M. D., J. W. Moore, D. E. Schindler, and C. J. Harvey. 2007. Varying effects of anadromous salmon on the trophic ecology of two species of resident stream fishes in southwest Alaska. Freshwater Biology 52:1944-1956.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters, 2nd edition. Griffin and Company, Ltd. London.

Shapovalof, L., and A. C. Taft. 1954. Life histories of the steelhead rainbow trout (*Salmo gairdneri gairneri*) and silver salmon (*Oncorhynchus kisutch*). California Department of Fish and Game Bulletin Number 98:1-303.

Walker, R. J., C. Olnes, K. Sundet, A. L. Howe, and A. E. Bingham. 2003. Participation, catch, and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Fishery Data Series No. 03-05, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds03-05.pdf

Wallis, J., D. T. Balland, and D. Thomas. 1984. Anchor River steelhead study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, F-9-16 (25) AFS-48, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/FREDf-9-16(25)AFS-48.pdf

Ward, B. R., and P. A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead (Salmo gairdneri) and the relationship to smolt size. Canadian Journal of Fisheries and Aquatic Sciences 45:1110-1122.

Ward, B. R., and P. A. Slaney. 1993. Egg-to-smolt survival and fry-to-smolt density dependence of Keogh River steelhead. [In]: Gibson, R. J., and R. E. Cutting, editors. Production of Juvenile Atlantic salmon, (Salmo salar), in natural waters. Special Publication 118. Canadian Journal of Fisheries and Aquatic Sciences:209-217.

Ward, B. R., P. A. Slaney, A. R. Facchin, and R. W. Land. 1989. Size-biased survival in steelhead trout (*Onchorhynchus mykiss*): back-calculated lengths from adults' scales compared to migrating smolt at Keogh River, British Columbia., Canadian Journal of Fisheries and Aquatic Sciences 46:1853-1858.

Withler, I. L. 1966. Variability in life history characteristics of steelhead trout (Salmo gairdneri) along the Pacific coast of North America. Journal of Fisheries Research Board of Canada 23:365-393.

Wright, B. 2004. How wild steelhead win the race. 2004 Annual Alaska Chapter AFS Conference, Sustaining Alaska's Fisheries: Visions for the Future. Harrigan Centennial Hall, Sitka Alaska, Nov. 16-18, 2004.

REFERENCES CITED (Continued)

Wuttig, K., D. Fleming, and J. Olsen. 2004. Stock status and population biology of the Copper River steelhead. Alaska Department of Fish and Game, Fishery Data Series No. 04-18, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds04-18.pdf

Yanusz, R. J. 1997. Status of sea-run cutthroat trout, sea-run Dolly Varden, and steelhead populations at Sitkoh Creek, Southeast Alaska, during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-23, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds97-23.pdf

APPENDIX A: FILE DESCRIPTIONS

Appendix A1.–Contents of electronic files submitted with this report.

FILE NAME	SOFTWARE	CONTENTS
0506FDS_Tables_Figs.xls	Excel 2003	Figures and tables and associated data and Appendices used to generate them for this report
0506Sitkoh_Data.xls	Excel 2003	Sample and tag numbers, lengths, scale sample and genetic sample numbers, otolith sample number, dates samples collected for steelhead adults and juveniles at Sitkoh Creek weir during 2005 and 2006
05Sitkoh_DV_CT_lengths.xls	Excel 2003	Cutthroat trout and Dolly Varden char lengths at Sitkoh Creek weir collected in 2005
06Sitkoh_DV_CT_lengths.xls	Excel 2003	Cutthroat trout and Dolly Varden char lengths at Sitkoh Creek weir collected in 2006
05Daily_Cum_Counts.xls	Excel 2003	Daily weir counts in 2005 for all species at Sitkoh Creek
06Daily_Cum_Counts.xls	Excel 2003	Daily weir counts in 2006 for all species at Sitkoh Creek
0506Sitkoh_Temp_Level.xls	Excel 2003	Daily temp and stage gauge at Sitkoh Creek in 2005 and 2006